CHARACTERIZATION AND TEST TREATMENTS OF CAST-STONE MEDALLIONS AT THE SMITHSONIAN

C.A. Grissom[1*], E. Aloiz[2], E.P. Vicenzi[1], N.C. Little[1] and A.E. Charola[1]

Abstract

The Smithsonian Institution's Arts and Industries Building (1879-1881) is decorated with 48 medallions and 24 spandrels molded in cast stone. Their gray coloration mimics more costly Euclid bluestone otherwise used for the brick building's trim. The fabricator of the medallions and spandrels, Saxon immigrant Charles Seltman, is newly identified, and their fabrication is placed within the history of American decorative concrete. The cast-stone material and its deterioration were characterised primarily using light microscopy and scanning electron microscopy accompanied by hyperspectral energy dispersive analysis (SEM-EDS). Cross-sections showed that each casting was made in two layers: a fine-grained, well-bound surface layer measuring 2-3 mm in thickness above a more porous layer with large quartz aggregate and smaller ilmenite and hematite particles; the binder in both layers was a mixture of lime and pre-rotary kiln Portland cement. Loss of the more durable surface layer has exposed the weaker lower layer on at least a third of medallion surfaces, invariably those higher in relief, and dissolution of these higher-relief surfaces appears to be ongoing. SEM-EDS showed that uptake of atmospheric sulfur oxides has resulted in conversion of calcite to more soluble gypsum to a depth of ~50 μm in a well-preserved area and to a much greater depth where the surface layer has been lost. With the goal of selecting the best treatment for potential conservation in future, tests were performed on eight west facade medallions, including pre-treatment with ammonium carbonate, consolidation with Prosoco's Conservare OH 100 (an ethyl silicate solution) or barium hydroxide, and application of ammonium oxalate as a protective coating. Photography, colorimetry, water absorption, and adhesive tape testing were performed before and after test treatments. The best method for determining the success of treatment appears to be assessment of surface-layer loss based on comparison of photographs over the long term.

Keywords: cast stone, ethyl silicate, barium hydroxide, ammonium carbonate, ammonium oxalate

[1] C. Grissom*, E. Vicenzi, N.C. Little and A.E. Charola
Museum Conservation Institute (MCI), Smithsonian Institution, United States of Amirca, grissomc@si.edu

[2] E. Aloiz
John Milner Associates Preservation, United States of America

*corresponding author

1. Introduction

The Smithsonian Institution's Arts and Industries Building (1879-1881) in Washington, DC, was designed by the architects Adolf Cluss and Paul Schulze to house the U.S. National Museum and is sometimes said to be the least expensive federal building per square meter ever erected. It was almost certainly to minimize costs that 48 decorative medallions and 24 spandrels were molded in gray-coloured cast stone to mimic more costly Euclid bluestone otherwise used for the red brick building's trim. The building's exterior elevation is identical on all four facades (Fig. 1): six medallions are installed between window arches on a pair of ranges on either side of a tower and six spandrels in corners above three window arches on the tower itself. Each medallion is identified here by the cardinal direction of the façade (N, S, E, or W) followed by a number from 1 to 12, left to right. Two flower designs alternate on the building, distinguished by rounded or pointed petals and leaves. The condition of the medallions was chosen for further study from 2011 to 2013, when they were accessible from scaffolding erected for the building's restoration. The material and its deterioration were analysed, and conservation test treatments were applied and evaluated.

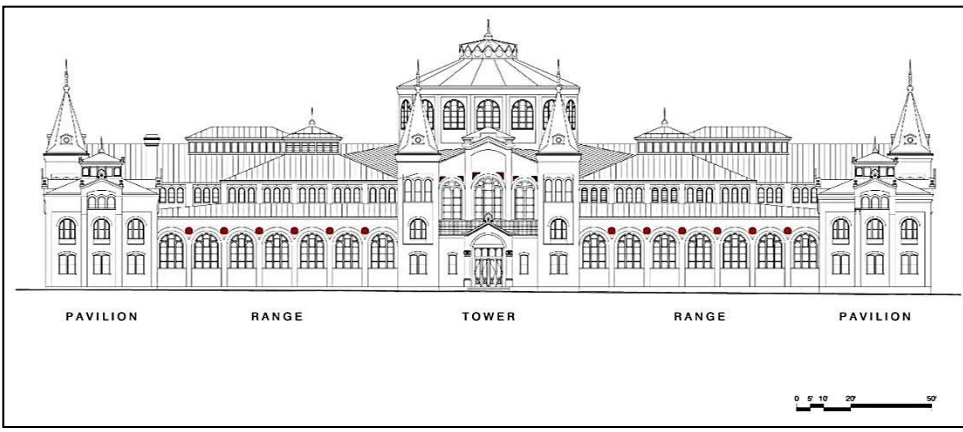

Fig. 1: Exterior elevation of the Smithsonian Institution's Arts and Industries Building (1879-1881). Medallions and spandrels are indicated in solid red.

2. Characterization of the cast stone

2.1. Description

The medallions measure 61 cm in diameter; perimeter rims are recessed 2 cm from the brick wall, but areas of highest relief (on leaves) project slightly from the brick. The medallions were cast face down, confirmed by smooth finishes on well-preserved areas and settlement of silt-sized silica particles (<50 µm) at surfaces. A thin section made from a well-preserved, smooth-surfaced area of medallion N5 shows that two layers were used to mold each casting (Fig. 2): a fine-grained, well-bound surface layer 2-3 mm thick above a much more porous, poorly bound layer containing large silica (quartz) aggregate and small opaque particles of black ilmenite ($FeTiO_3$) and iron oxide, probably hematite (Fe_2O_3). In both layers the binder was identified microscopically as lime mixed with pre-rotary kiln

Portland cement (John Walsh, pers. comm.). Hydrochloric-acid digestion of a sample from the lower layer found (by weight) 42% effervescing acid-soluble material; 50% aggregate, dominated by rounded to angular quartz as large as 1.5 mm in the longest dimension and smaller amounts of ilmenite (a component of some sands) and iron oxide measuring up to about 0.2 mm in largest dimension; and 8% fines consisting mainly of very finely divided gray quartz. The cast stone is porous. Surface water absorption using vertical RILEM tubes is rapid compared to stone, measuring 5 minutes for 5 ml of water in a well-preserved area.

Fig. 2: Thin section from a well-preserved, smooth-surfaced area on N5 in transmitted light; calcite is stained yellow and the epoxy medium, blue. The cross-section shows two layers: a dense surface layer and a more porous lower layer with large quartz aggregate (white in this image) and small black ilmenite particles. Width of sample is 11 mm. Photo by Mel Wachowiak.

The fabricator of the medallions and spandrels, hitherto unknown, is now identified as the Washington-based Saxon immigrant Charles Seltman (1827-1907), “Modeler & Pattern-maker.” Seltman was paid the first $80 of a total of $355 for “Modelling 2 rosets [the medallions] and 2 corner ornaments [the spandrels] for the four Main Walls, making casts of same and making and furnishing the boxes for molding the same in Portland cement” (Invoice 1879). This use of cast stone was relatively early in the United States (Prudhon 1989). Just ten years before, the French inventor François Coignet had applied for nine American patents for artificial stone and monolithic concrete. In 1870, rights to Coignet’s patents were sold to John C. Goodridge, Jr., superintendent of the Brooklyn-based New York and Long Island Coignet Stone Company (Goodridge 187-, Gillmore 1871, Chamberlin 1983). The company’s polychromed Cleft-Ridge Span (1871-1872) by Calvert Vaux in Brooklyn’s Prospect Park demonstrated the ornamental potential of molded concrete, and its products may have served as an impetus for use of cast stone on the new museum building.

2.2. Deterioration

All 48 medallions were surveyed and photographed. They were found to be in remarkably good condition given 135 years of weathering. None was found to have major cracks, and it proved a challenge to find damaged areas for minimally invasive sampling. Of concern, however, is the loss on all medallions of at least a third of the smooth, dense surface layer, invariably from areas of higher relief (Fig. 3 and Fig. 4). Evaluation of the porosity of the two layers was hampered by the inaccessibility of intact surface layers in recessed areas. However, RILEM tube tests consistently showed that rims with partial surface retention absorbed water at half the rate of higher-relief leaves on which the surface layer has been lost.

Fig. 3: Medallion W10, before treatment (January 30, 2013).

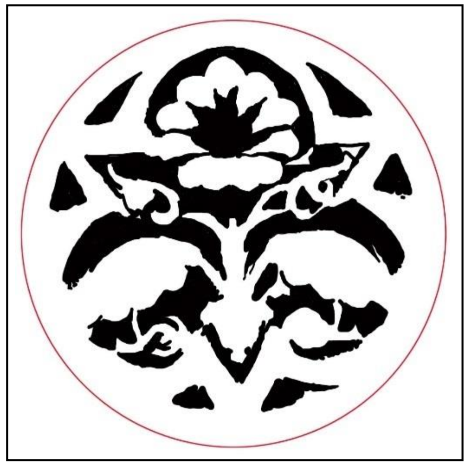

Fig. 4: Drawing after the previous, with areas retaining the surface layer marked in black; such areas are invariably lower in relief.

The cause of surface loss was investigated in cross-sections. Deterioration in the form of conversion of calcite to gypsum following uptake of atmospheric sulfur oxides was found even where the surface layer is still present, as in Fig. 2. An SEM image of that sample shows sulfur to a depth of ~50 µms from the surface (Fig. 5). On a sample from medallion S9 taken from an area that has lost most of the surface layer, in contrast, calcite was found to have converted to gypsum to a depth of ~250 µm (Fig. 6); below that, an even thicker zone of mixed gypsum and calcite was present. Thus, it appears that loss of the surface layer has increased the depth of conversion to gypsum, probably in part because of the porosity of the lower layer. A major source of sulfur was almost certainly coal, used to heat the Arts and Industries building until around 1910. The amount of airborne sulfur in the vicinity of the building has been limited since then, and the current rate of sulfation of the medallions should be minimal. Deterioration, however, is likely ongoing because gypsum is approximately one hundred times more soluble than calcite. Several observations underline the key role that rainwater plays in deterioration. Greater water absorption during rainfall and slower drying afterward were observed on high-relief areas, in contrast to low-relief areas (cf. Fig. 7 and Fig. 8). Moreover, high-relief areas invariably appear clean and light, almost certainly from ongoing dissolution of gypsum by rainwater; while recessed areas are dark and smooth, with soiling retained by relatively intact surface layers (Fig. 3). Visual comparison also indicated that predominant rain directions play a role in greater surface-layer loss on west and north façade medallions compared to those on east and south façades. An unexpected finding was that both thin sections showed thin surface layers (~5-7 µm thick) enriched in fluorine (Fig. 5). This is attributed to past hydrofluoric acid or ammonium bifluoride cleaning of the building.

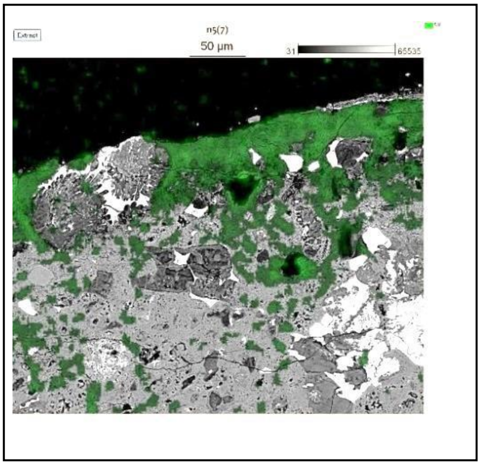

Fig. 5: SEM backscatter electron image of the fine-grained upper layer of thin section N5 (cf. Fig. 3) shows raw sulfur x-ray counts at the surface in green false colors to a depth of ~50 µm. The thin bright line at the upper right surface is enriched in calcium fluoride.

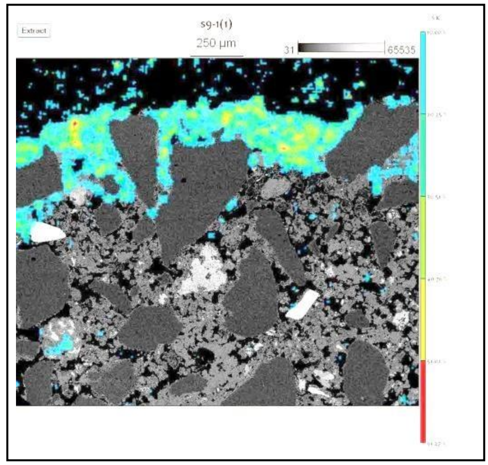

Fig. 6: SEM backscatter electron image of thin section S9, which has lost nearly all of the fine-grained upper layer, shows sul-fur to a depth of ~250 µm in false colors. Only sulfur above 10 atom per cent (blue on the bar at right) is displayed, ranging up to 61% (red on the bar). Large dark gray particles are quartz.

3. Testing

Concern about deterioration of the medallions has been limited, because they remain readable from a sculptural standpoint on account of relief areas being light in value and background areas dark (Fig. 3). Substantial loss of surface layers and conversion of calcite to gypsum, however, led to a proposal for test treatments. The relatively good condition of the cast stone and limited experience and literature in treating similar problems also rendered test treatments a sensible option.

Fig. 7: Medallion W9 after rainfall, before treatment (September 28, 2012). Low-relief areas are dry, indicated by their relative lightness; in contrast, when the entire medallion is dry, low-relief areas are darker than high-relief areas (cf. Fig. 8).

Fig. 8: Medallion W9 two-and-a-half years after treatment with ammonium carbonate, $Ba(OH)_2 \cdot 8H_2O$, and ammonium oxalate (July 16, 2015).

Tab. 1 lists test combinations of a pretreatment solution, two consolidants, and a coating applied to eight medallions on the west façade. These treatments were selected based on successful use on stone (Bracci 2008), modified for potential use on the building by a contractor. Pretreatment with ammonium carbonate is mainly intended to convert gypsum to more soluble ammonium sulfate. Poultice application produces optimal results because of prolonged exposure, and the method of Botticelli *et al.* (1984) for frescoes was employed on the first medallion treated, using Arbocel 1000 paper pulp. The cast stone appeared cleaner after removal of the poultice, but fragile black surface particles were also lost, and the process proved time consuming. Thereafter, saturated solutions of ammonium carbonate were applied by spray or brush. An ethyl silicate stone consolidant (Prosoco's Conservare OH 100 based on Wacker OH 100) was applied to deposit silica in the cast stone. On W1 it was spray applied at intervals of 5-15 minutes in three cycles of three applications each, per specifications for stone. On W4 twice the amount (~1 liter) was applied without refusal, and it seemed that absorption could continue *ad infinitum*. Barium hydroxide was applied to convert gypsum or remaining ammonium sulfate into highly insoluble barium sulfate, as well as to deposit insoluble barium carbonate. Although optimally applied by poultice, it was brush applied to avoid losses that occurred with the ammonium carbonate poultice, as well as because it would be a simpler method for use by a contractor. A saturated solution of ammonium oxalate is usually applied by poultice as a protective coating on stone sculpture, but again brush application was substituted.

Tab. 1: Test treatments.

#	Pretreatment	Consolidant	Coating
W1		Conservare OH by spray	
W4		Conservare OH (2x amt.) by spray	
W10	Ammonium carbonate by spray	6% $Ba(OH)_2 \cdot 8H_2O$, by brush	
W2	Ammonium carbonate poultice	6% $Ba(OH)_2 \cdot 8H_2O$, by brush	Ammonium oxalate by brush
W9	Ammonium carbonate by brush	6% $Ba(OH)_2 \cdot 8H_2O$, by brush	Ammonium oxalate by brush
W12		6% $Ba(OH)_2 \cdot 8H_2O$, by brush	Ammonium oxalate by brush
W11		6% $Ba(OH)_2 \cdot 8H_2O$, by brush	
W8			Ammonium oxalate by brush
W7			Siloxane PD

Each of the eight medallions was photographed in detail, and three types of testing were done before and after treatment. A ninth medallion treated before this study using a water repellent (Prosoco's Sure Klean Weather Seal Siloxane PD) was also tested. Water absorption rates were similar after treatment to those before treatment on both rims and leaves of medallions to which the mineral-based solutions had been applied; this was considered a favorable result, because it indicates that no undesirable alteration in porosity occurred. Exceptions were medallions that could not be properly tested because of water repellency: those treated with the water repellent (Siloxane PD) and Conservare OH 100, which remained hydrophobic even nine months after treatment. Colorimetric measurements made with a Konica-Minolta CR-300 colorimeter were limited to leaves because of the size of the instrument's head. They showed only small changes after treatment: slight yellowing of medallions treated with Conservare OH 100 and lightening of those treated with barium hydroxide, such as W9 (Fig. 8). These changes are not noticeable from ground level, however, and are expected to disappear with time. Tape tests were done with clear adhesive tape (Scotch tape). The tape was applied on both rough and smooth areas, rubbed gently several times, and removed. Since the medallions are symmetrical, mirror-image areas were tested before and after treatment. The tapes were photographed through a Wild microscope using a Leica camera, and negative images were compared by inverting them using Adobe Photoshop for easier assessment. However, consistent differences in the amount or size of particles removed before and after treatment could not be discerned. For assessing the effectiveness of the test treatments over the longer term, comparison of photographs appears to represent the best option, since loss of the surface layer can be seen. Four years after the medallions were first photographed and nearly three years after treatment, no further loss of the upper layer can be discerned on all twelve west façade medallions, both treated and untreated.

4. Conclusion

Light microscopy and SEM EDS of thin sections of early decorative cast-stone medallions on the Smithsonian's Arts and Industries Building show that deterioration has occurred even on apparently intact surfaces, but to a far greater depth where the surface layer has been lost on areas of highest relief and a coarser lower layer is now exposed. Conservation treatments were tested; however, this project illustrates the challenges of treatment evaluation in the short term. Future examination of the medallions by comparison to photographs taken in the course of the present project is expected to determine the best method for treatment among those applied to eight medallions on the west façade.

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