

Tech Notes

NATIONAL PARK SERVICE
U.S. DEPARTMENT OF THE INTERIOR
WASHINGTON, D.C.

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MASONRY

NUMBER 1

Substitute Materials: Replacing Deteriorated Serpentine Stone with Pre-Cast Concrete

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SIX LOGAN CIRCLE Washington, D.C.

Constructed in 1878 from the designs of architect Henry R. Searle, Six Logan Circle is a five-story rowhouse which features a highly articulated facade of green serpentine stone laid up in a veneer of quarry-faced, random-ashlar blocks with Pennsylvania red brick trim. Located in the Logan Circle National Register Historic District in Washington, D.C., this building sits directly on Logan Circle, an original open space design element of the 1790s plan for the Federal City by Pierre L'Enfant.

Constructed for Naval Commander Allen V. Reed, the property remained a single-family residence until 1940 when

the Reed family sold the building. Typical of many of the large residential properties within the district, Six Logan Circle was subdivided and converted into a multiple-unit dwelling after World War II. Over the next forty years the building functioned as a nine-unit apartment complex and received little maintenance during this time.

In 1982, the property was purchased by the Six Logan Circle Associates with the intent of rehabilitating the property into six residential units. A major component of the rehabilitation focused on selecting a treatment for the extremely deteriorated serpentine stone facade.

Use of carefully selected substitute materials as replacement for severely deteriorated masonry is appropriate in limited cases.



Problem

Serpentine stone was frequently used as a building material in the late 19th century because of its distinctive greenish color. Numerous residential and moderate-scale institutional buildings were constructed using serpentine for entire facades or simply as a trim material in urban areas such as Philadelphia, New York, Washington, Baltimore and Chicago, as well as in rural areas close to the quarries such as Chester County, Pennsylvania, and northern Maryland. However, serpentine's popularity was short-lived because of its fragility.

Serpentine is a soft stone composed primarily of hydrous magnesium silicate which is basically the same mineral found in talc. It is not tightly consolidated, but a fibrous material that tends to absorb water. The presence of water accelerates the deterioration of the stone due to the effects of the expansion and contraction of the stone during freeze/thaw cycles. Since serpentine is an alkaline stone, it is also sensitive to attacks from sulphuric and sulphurous acids, and carbon dioxide dissolved in rainwater.

A stone consultant was retained to assess the condition of the serpentine stone and to recommend remedial work. The consultant conducted an in-depth visual inspection and evaluation and concluded that the serpentine stone was spalling extensively, due to the inherent softness and poor quality of the stone and the chemical forces interacting with the stone. The deterioration had been further exacerbated by the general lack of maintenance the building had received for the last forty years which had allowed large amounts of moisture to penetrate the stone. Moisture, laden with acids, had entered the stone through open mortar joints and the delaminated surface, accelerating the stone's deterioration. In this case, the problem was compounded by additional moisture spilling onto the surface of the serpentine from clogged, leaky, and inoperable gutters, downspouts and drains. Given the inherent problems with serpentine stone as an exterior building material and its overall advanced deterioration on Six Logan Circle, the consultant recommended that the serpentine stone, which was used as a veneer covering structural brickwork, be replaced rather than attempting a repair using traditional patching techniques. This conclusion was supported by a survey undertaken to determine how many of the stones

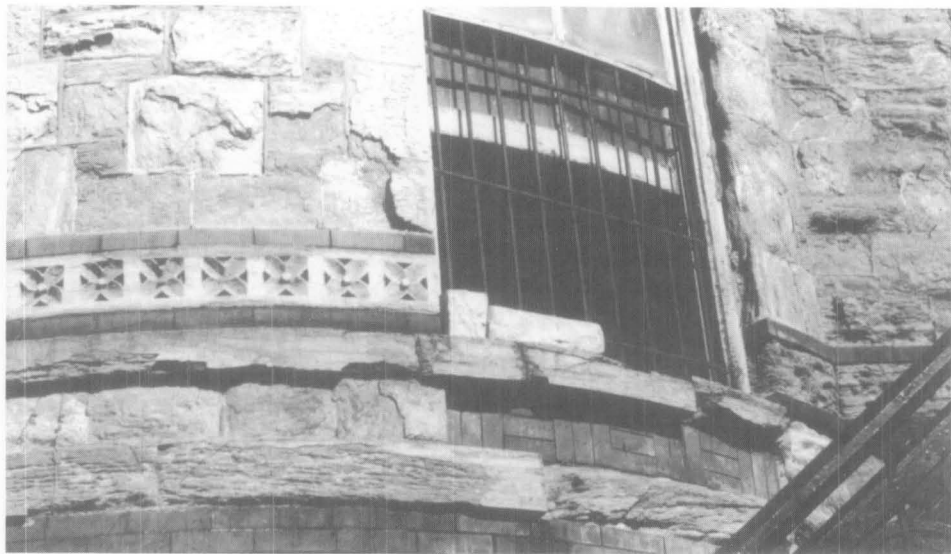


Figure 1. Close-up view of the deteriorated serpentine stone facade showing substantial surface delamination. Photo: Anne Grimmer

retained their integrity (i.e., how many remained substantially free of fractures and crumbling and retained their surface tooling, texture, and shape). The survey showed that 868 of the original 946 face stones which made up the facade no longer retained their integrity. In fact, many were so deteriorated that they could literally be pulled apart by hand (see figure 1).

Solution

Because only 78, or less than nine percent, of the stones remained intact, total replacement of the historic stone was justified in this particular case. However, the replacement material needed to closely match the historic stone in size, shape, dimension, texture and color in order to preserve the historic character of the facade. To meet these requirements, three replacement alternatives were considered:

1. Replacement in kind with new serpentine stone
2. Replacement with another type of natural stone
3. Replacement with a substitute material such as pre-cast concrete

Although replacement in kind is generally the preferred preservation approach when dealing with a non-repairable material, serpentine stone is no longer quarried for use as an exterior building material due to its poor performance historically. It is thus not readily available for large-scale applications such as that proposed for Six Logan Circle. An alternative stone (such as limestone) could be cut to match some of the visual characteristics of serpentine, but it could not duplicate its distinctive green coloring.

Therefore, the material that offered the most potential for use as a replacement material was pre-cast concrete. This material had recently been used to replace extensively deteriorated brownstone on the Renwick Gallery of the Smithsonian Institution in Washington, D.C., and it was determined by the consultant (who had worked on the Renwick Gallery restoration), that the same technology could be successfully applied to replace the serpentine stone at Six Logan Circle.

Work Description

Before the new cast stone could be manufactured, the existing serpentine stone facade had to be recorded. An architecture student was hired to measure each existing stone on the facade and prepare precise drawings of the elevation, showing the size and location of each stone. Each stone was assigned two numbers—an individual identification number and a number indicating the stone's shape and size. These key numbers were marked directly on the measured drawings. Drawings were prepared for the plainer stones that made up the major portion of the facade as well as the decorative trim stones (see figure 2). From these drawings, a master list of all the stones and their sizes was compiled, which was used to guide the casting and manufacturing processes. Later, as each new stone was fabricated, it was noted on the drawings so that an up-to-date inventory could be maintained.

As revealed by the earlier condition assessment survey, 78 intact stones still displayed their original shapes, sizes,

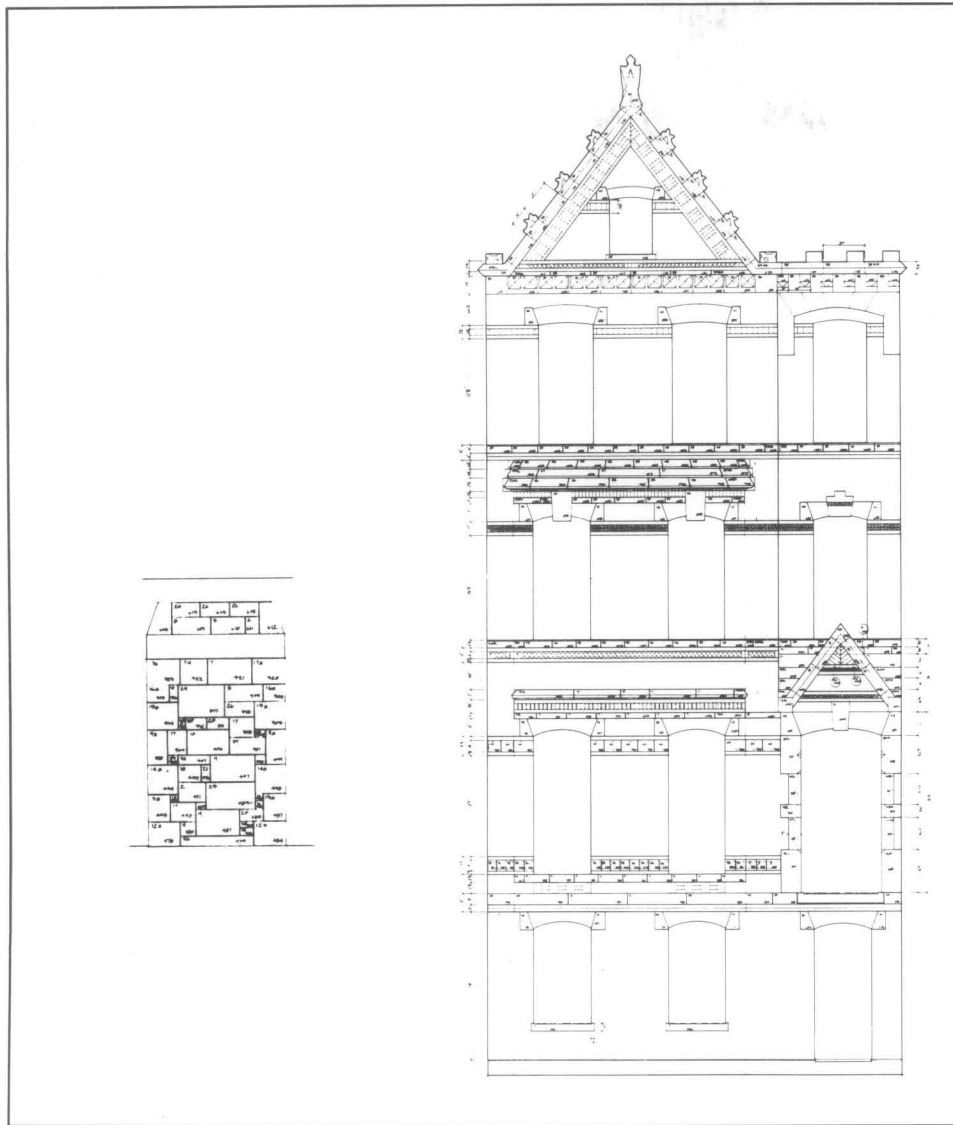


Figure 2. Two measured drawings were made of the facade, one showing the individual field and jamb blocks, and the other, the decorative trim stones. The identification number and the shape and size number of each stone were marked on the drawings. Drawings: Rich Layman

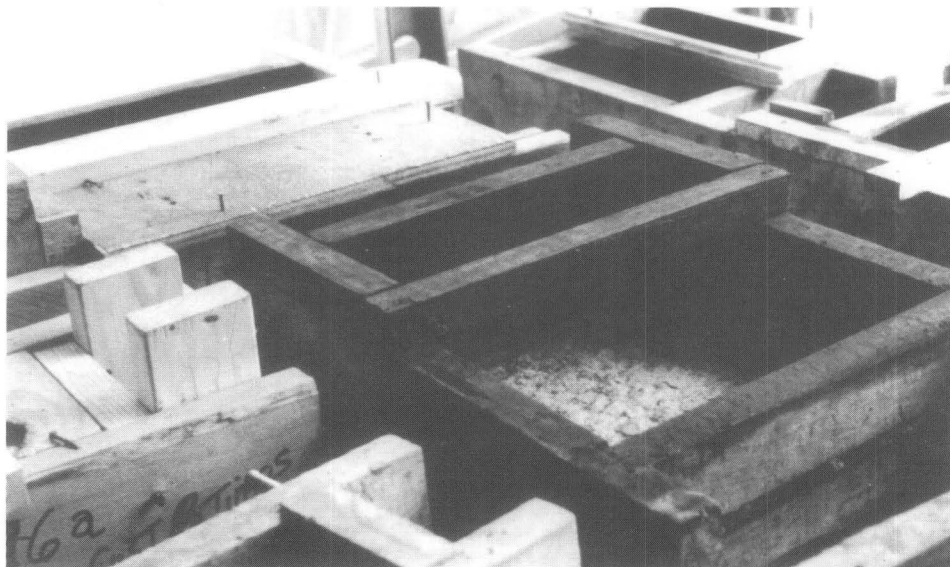


Figure 3. Concrete was poured into these wooden forms which were specially constructed, and reinforced with steel rods and bolts, to hold the built-up molds of the original stones. Once placed in the wooden forms, the built-up molds thus served as the casting models. Photo: Robert Powers

and textures. These particular stones were fortunately diverse enough to provide a representative sampling of the entire facade and thus served as models for reproduction. The following process was used to reproduce the shape, size and surface texture of the serpentine blocks:

1. A release agent was sprayed on each stone of the facade to be reproduced.
2. Latex molding rubber was then brushed-on in layers to the surface of the stone, still *in-situ*, to obtain an impression of the stone's surface. From these latex molds, the surface qualities of the individual blocks of the serpentine facade could be faithfully reproduced in the casting process.
3. The latex mold was removed from the stone and in the workshop the mold was built up with plaster to increase the crispness of the details.
4. This built-up mold, when placed in a specially constructed wooden framework reinforced with steel rods and bolts, became the casting mold.
5. A release agent was applied over the formwork and the built-up mold. Then the concrete was poured into the casting mold (see figure 3).

Although the above process worked well for over 90% of the stones to be replicated, the remainder of the stones needed for models were too deteriorated to take a face impression *in-situ*. In those situations, the stone was carefully removed from the wall and these additional steps were followed:

1. A bonding agent was applied to the surface of the stone to be reproduced.
2. Using the more intact stones as models, the stone's surface was built up with a mixture of portland cement and sand to approximate as closely as possible the stone's original surface, shape, and texture.
3. After the built-up stone was dry, the same process described earlier was followed to create molds of these stones (see figures 4-6).

The owners were fortunate to have a rear yard large enough to establish an approximately 1100 square feet workshop on-site for manufacturing the new pre-cast concrete units. By casting the stones on-site instead of sending the molds to be poured at another location, they eliminated shipping costs. The enclosed temporary shed constructed to house the "manufacturing plant" con-

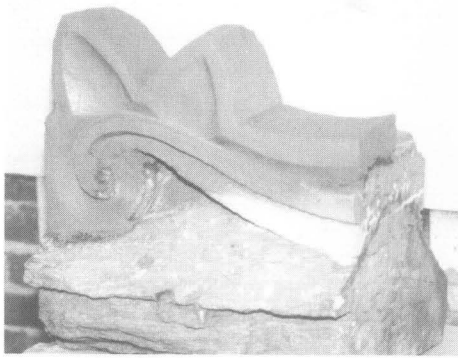


Figure 4. Most of the rubber castings could be made directly from stones still in place on the facade, but the more deteriorated stones first had to be removed from the wall. After their removal from the wall, a bonding agent was applied to the deteriorated stone surface, and a new stone surface was created replicating the original design details with concrete. Photo: James Smith

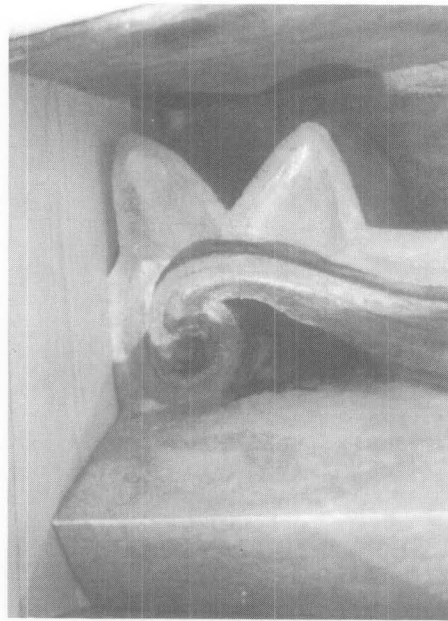


Figure 5. A latex casting mold was made from this recreated "built-up" stone surface by brushing on layers of latex molding rubber. Photo: James Smith

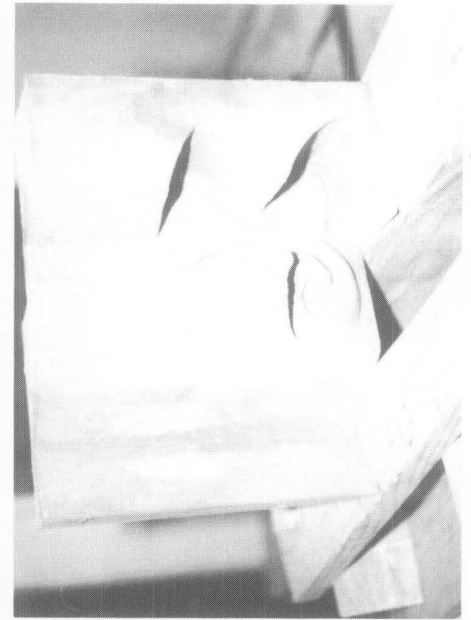


Figure 6. A rubber impression made from this latex casting mold then provided the mold into which the concrete was poured to create the new pre-cast units. Photo: James Smith

sisted primarily of a stud wall system with polyethylene wall covering. Portable kerosene heaters provided heat for the workmen as well as the warm temperatures necessary for the stone manufacturing and curing processes during the winter months.

The process of manufacturing the new concrete stones was carried out by a crew consisting on the average of three laborers to make molds and take impressions, and four laborers responsible for removing the cast units from the molds and cleaning them. These workers were under the supervision of the consultant and the contractor who trained them in each step of the process. The process consisted of five steps:

1. Measuring and mixing the materials.
2. Checking for quality control.
3. Pouring and vibrating the concrete.
4. Air curing, mold removal and inspection.
5. Removing soluble salts by submerging in a water tank.

Mixing the Materials

The concrete mix was composed of the following materials:

- White portland cement meeting ASTM C-150 Type I standards
- Inorganic masonry pigment, chromium oxide green as

manufactured by Mineral Pigments Corporation

- Coarse aggregate (gravel) 3/8 to #4 "Eau Claire", dry and bagged
- Fine aggregate (concrete sand), "Eau Claire" passing a #16 screen, dry and bagged
- Air-entraining agent (liquid admixture of the vinsol resin type conforming to ASTM 260-77)
- Water-reducing agent, liquid type conforming to ASTM C-494, "Chemical Admixture for Concrete," Type A (Pozzolith 122-N)
- Water, clean, clear, potable with a pH reading between 5-8 and the conductivity not exceeding 100 MILLIMHOS on the 0-200 scale

These materials were mixed in a paddle mixer large enough to combine the materials so that each batch would not exceed the number of molds that could be vibrated without tempering the mix with water. Each day, before the start of mixing, a minimum of 2 cubic feet of design mix "butter" was run through the cleaned mixer and dumped. This procedure seasoned the mixer. If another batch was mixed within 30 minutes, the remnants of the previous batch was used as the "butter". The mixer was cleaned at the end of each day.

Finding the exact concrete mix to replicate the color and appearance of historic stone is usually a matter of some experimentation. However, in this

case, by using the successful formula derived in part from the work on the Renwick Gallery, the only major obstacle was finding the proper pigment color that would match the serpentine stone, and would not fade. After a series of test stones were manufactured and fully cured, a close color match was established. The mix that produced a color closest to that of the serpentine stone, and also meeting all the required strength tests, was composed of the following materials in the quantities indicated (the quantities shown are in pounds for 1/2 cubic yards):

- White portland cement - 376 lbs.
- Pigment - 12 lbs.
- Fine aggregate - 700 lbs.
- Coarse aggregate - 775 lbs.
- Water - 150 lbs.
- Vinsol resin - 4 oz.
- Pozzolith 122-N - 18 oz.

These materials were combined in the following sequence:

- Fine and coarse aggregate
- Maximum of 2/3rds of the water
- White portland cement
- Pigment
- Admixtures
- Remaining water

The materials were combined in the mixer until there was a consolidated, homogeneous concrete of the required slump—usually about two to three minutes and always less than ten minutes.

Quality Control

Once the materials were thoroughly mixed and ready to be poured, measures were taken to ensure that the newly-fabricated pre-cast units met the specified strength criteria. In the manufacturing process adopted for Six Logan Circle, a minimum of 6 standard testing cylinders (6"×12") were filled from a selected batch once a day, and sent to a testing laboratory. Two of the cylinders were tested for compressive strength at 7 days and at 28 days. The remaining cylinders were retained for 56 days for additional testing before disposal. A minimum of 2 standard 6"×12" cylinders cast from all the other batches was collected and also tested for compliance with the design criteria of 5,000 psi at 28 days.

Pouring the Concrete

The consolidated and homogeneous concrete mix was poured from the mixer into the specified mold which had already been placed on the vibration table. The vibrating process forces the entrained air and surface air out of the mold, eliminating in most cases the possibility of surface imperfections from air bubbles. Proper vibration of the newly poured concrete was extremely important to obtain a high quality pre-cast concrete. The vibration table operated at a rate of 2,600 vibrations per minute and could accommodate all the castings from a batch within thirty minutes after mixing. Small cast units required approximately sixty seconds of vibration and the larger ones required approximately ninety seconds. A cake spatula was effective in cutting many of the air bubbles from the surface of the sides of the mold during the first ten seconds of the vibration process (see figure 7).

Air Curing, Mold Removal and Inspection

After the vibration process was completed for each stone, the molds were placed on heated benches for sixteen hours, after which the molds could be gently removed without damaging the stone. Each stone was then inspected for any visual inconsistencies or other imperfections from the mixing, pouring and vibrating processes. The stones were evaluated for problems such as uneven or non-matching coloring, chips, exposed aggregate, air bubbles (pin holes), or depressions. During the manufacture of the new pre-cast stone,

more than 400 newly cast stones were rejected due to surface deficiencies.

Removing Soluble Salts

The final step in the manufacturing process was essential to the successful outcome of the product. In this step, the stones were submerged in a water tank for a period of six hours, then removed and dried for six hours (see figure 8). The drying process forced soluble salts inherent in the concrete mix to the surface of the stone. An application of a weak solution of muriatic acid with a thorough water rinse was used to wash away the leaching salts. This procedure of soaking and drying was repeated three times for every stone. After completing this process, each stone was transferred to the base-ment for storage on wooden skids.

Installation

Before any of the original stone was removed, the corresponding section of pre-cast material was arranged in the



Figure 7. The workmen shown here are cutting the air bubbles from the sides of the mold using a cake spatula during the first 10 seconds of the vibration process. Photo: James Smith



Figure 8. After soaking for 6 hours to remove soluble salts in a polyethylene-lined wood water tank, the pre-cast units were allowed to dry for another 6 hours. This process was repeated 3 times for each pre-cast unit. Photo: James Smith

“staging area” in the basement. Using the measured drawings and numbering system prepared earlier, the blocks of cast stone were assembled on the basement floor on top of 4” of sand. Assembling them in the staging area allowed for a final inspection of the blocks and also allowed the master mason to arrange the new stones during a “dry run” prior to the actual installation on the building, thereby minimizing problems once the work on the building began (see figure 9).

Once all the new pre-cast concrete blocks were manufactured, inspected and fully cured, the process of dismantling the existing deteriorated facade and installing the new material began. Since the serpentine stone was used as a veneer covering structural brickwork and was not itself a structural element, sections of the veneer could be removed without jeopardizing the stability of the building.

With the front elevation fully scaffolded, sections of the serpentine stone and ornamental brick were removed. Because the brick trim was in excellent overall condition and was to be reused in the new facade, it was carefully removed with hand tools, inventoried, and stored for reinstallation. With the serpentine and face brick removed, necessary repairs were made to the structural brick, and stainless steel anchors for the new pre-cast veneer were installed. The new cast stones were hoisted up the scaffolding on wide belt slings with an electric winch and installed in place (see figure 10).

Since the new pre-cast concrete blocks are much harder than the original serpentine stone, a mortar mix containing a large proportion of white portland cement was used. However, other than the composition, the new mortar joints match the light-colored, raised mortar joints used on the original stone facade. The walls were then backfilled with a parging material.

The original bricks were individually cleaned with bristle brushes and water before being reset into the new facade. The new brick mortar was based on an analysis of the original, dark-colored brick mortar and matched it in composition, color, texture, joint width and profile. (see figure 11).

Project Evaluation

After nine months of work, the installation of the new pre-cast facade for Six Logan Circle was completed at the cost of \$225,000, or slightly less than one-fourth of the total project cost. The



Figure 9. Using the measured drawings as a guide, the pre-cast units were assembled in the staging area on top of 4 inches of sand prior to their installation on the facade. Photo: Robert Powers



Figure 10. The new pre-cast units were hoisted up the scaffolding on wide belt slings with an electric winch, and installed in place using a portland cement-based mortar appropriate for cast-concrete. The original bricks were relaid with a more traditional lime-based, dark-colored mortar. Photo: James Smith

project was considered a success by all the participants; the stated goal of removing the crumbling serpentine veneer and replacing it with a new material that returned the facade to its original appearance was met. The building has a renewed presence with its pre-cast concrete units molded to match the form of the original stone, and exhibits a crispness of detail, texture and color that had been absent for many years (see figure 12).

Some of the trim pieces, in particular the floral blocks as well as units in the belt coursing and window sills, do have noticeable surface imperfections when

viewed up close, such as indentations caused by air bubbles and in a few instances the aggregate is exposed, indicating a poor concrete mix. Ideally, each of these units should have been rejected during the inspection stage. However, the small number of such pieces does not detract from the overall appearance of the rebuilt facade.

The manufacture and installation of the new pre-cast concrete units and historic brick was an expensive undertaking; however, in this case, alternative options were very limited. The new owners chose this course of action

because of their desire to find a long lasting solution to a difficult problem. This approach may not be appropriate in all situations involving deteriorated serpentine or other types of historic masonry. Total replacement of the deteriorated stone veneer of a historic building using a substitute material should be considered only after careful analysis. If, after a thorough examination of all possible alternative treatments, a replacement approach is selected, the project should be undertaken only by qualified personnel under professional guidance and supervision.

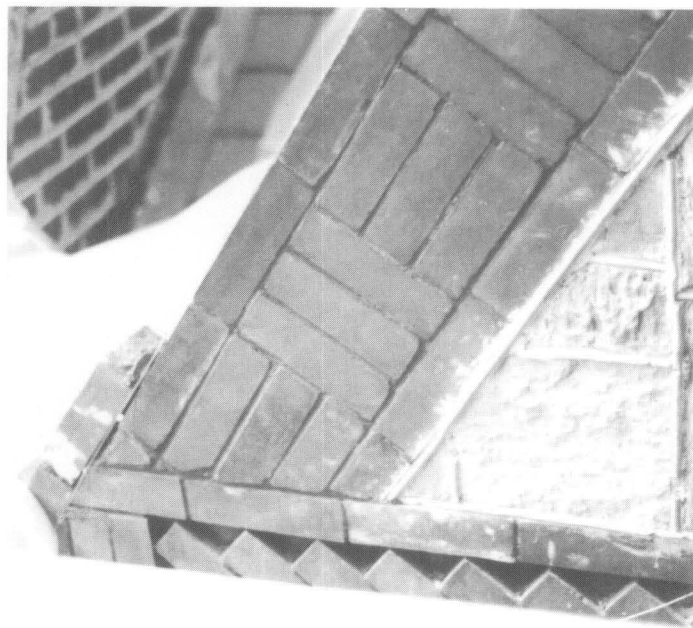


Figure 11. Close-up views of the newly installed pre-cast concrete units and the reinstated original brick. Photo: James Smith

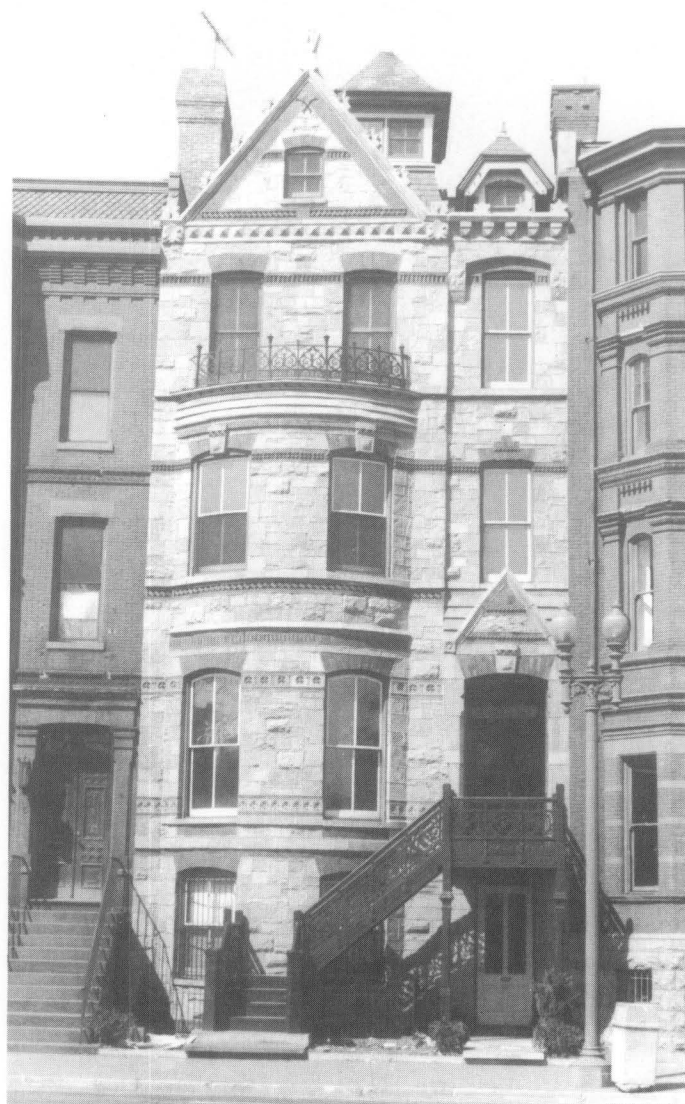


Figure 12. The house after rehabilitation. Photo: Anne Grimmer

PROJECT DATA:**Building:**

6 Logan Circle
Washington, D.C.

Owner:

Six Logan Circle Associates
James F. Smith and Allan G. Bortel,
General Partners
Washington, D.C.

Project Dates:

November 1984-July 1985

Stone Consultants:

Gary R. Brenner
Gaithersburg, Maryland
Dr. Seymour Lewin
New York University
New York, New York

General Contractor:

Construction Consultant Services, Inc.
James F. Smith, President
Washington, D.C.

Project Cost:

\$1,044,804 Total project rehabilitation
cost
\$ 233,000 Replacement of masonry
veneer using new pre-cast
units and original
bricks—includes material,
equipment and labor

This PRESERVATION TECH NOTE was prepared by the National Park Service. Charles E. Fisher, Preservation Assistance Division, National Park Service, serves as the Technical Coordinator for the PRESERVATION TECH NOTES. Information on the cast-stone replacement system described here was supplied by James F. Smith, General Partner and Contractor for the project, and Gary R. Brenner and Seymour Lewin, project consultants. Special thanks go to the following National Park Service staff who contributed to the production of this Tech Note: Martha Raymond, Dennis Montagna and Varnetta Ross of the Mid-Atlantic Regional Office, and Anne Grimmer, Theresa Robinson and Brenda Siler of the Preservation Assistance Division. Cover Photo: Six Logan Circle, before rehabilitation.

PRESERVATION TECH NOTES are designed to provide practical information on innovative techniques and practices for successfully maintaining and preserving cultural resources. All techniques and practices described herein conform to established National Park Service policies, procedures and standards. This Tech Note was prepared pursuant to the National Historic Preservation Act Amendments of 1980 which direct the Secretary of the Interior to develop and make available to government agencies and individuals information concerning professional methods and techniques for the preservation of historic properties.

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