Replicating the John J. Earley Concrete Mix to Restore the Nashville Parthenon

ILENE R. TYLER

Laboratory analysis and prototype testing determined an accurate match of the materials used to restore the Nashville Parthenon.

The 1925 Nashville Parthenon is constructed largely of concrete with aggregate intended to simulate the color and texture of quarried stone. Concealed within the concrete skin is the building's structure: the foundation is coursed rubble limestone; the walls are brick masonry; and the roof has steel trusses bearing on steel columns. The sloped roof deck is constructed of cast-in-place concrete covered by pre-cast concrete roof tiles. A recently completed program of comprehensive repairs to the exterior envelope included replication of the concrete, restoration of extant sound concrete, repair of concealed substrate and structure, exterior cleaning, application of a corrosion inhibitor and a water repellent, and decorative painting of the plaster soffit. This paper focuses on the methods used to investigate, document, and restore the concrete.

Figure 1, which illustrates the components of the Doric order, is a useful reference for understanding the terminology used in this paper. This drawing, of the Athens Parthenon, illustrates the accuracy and true-to-scale replication of the Parthenon.

Historical Background

Originally built in 1896 of tinted plaster over a substrate of wood and brick, the Parthenon is the centerpiece of Nashville's Centennial Park and the only structure remaining from the Centennial Exposition of 1897 (Fig. 2). The architect for the Parthenon was Col. W. C. Smith and the engineer in charge of construction was Robert T. Creighton. The original construction was intended to last only one year, but, with much patching, the local landmark stood until 1920, when it was declared unsafe and closed to the public.[1]

The Nashville Board of Park Commissioners had been considering a more permanent replica of the Parthenon in Athens to replace the 1897 Parthenon and retained Nashville architect Russell E. Hart to research and recommend how this might be accomplished. Hart prepared plans for the concrete skeleton, and the Foster and Creighton Construction Company strengthened the old foundations and erected the structural frame. Whereas the Athens Parthenon had been carved in Pentelic marble quarried in Greece, this reconstruction would resort to modern materials, using cast-in-place concrete with colored aggregates simulating natural stone. Hart and the Nashville Park Commission approached the Earley Studio to execute the exterior finish and cast the sculptural metopes of the frieze and the statuary in the pediments. Having just completed several important projects that brought him acclaim for his creativity in the use of concrete, John J. Earley welcomed the challenge to complete a monumental work that separated structure and finish, concentrating his expertise in the preparation of extremely accurate molds and designing the mix that achieved the desired appearance.[2]

Replication of the Parthenon exterior was completed in 1925. Based on a vast amount of study and research, plaster molds of the heroic pediment sculptures were created from copies of the original sculptures by New York sculptors Belle Kinney and Leopold Scholz. Using Earley's specified mix, the pediment sculptures were cast on site, cured, finished by removing the molds while the concrete was still green and brushing away surface matrix to expose the aggregate, and lifted into place in the east and west pediments (Fig. 3). Clay models of the metopes were made by George Julian Zolnay, who had done the pediment sculptures for the 1896 building. These were shipped to Earley's studio in Washington, D.C., where they were cast in concrete and returned to Nashville to be

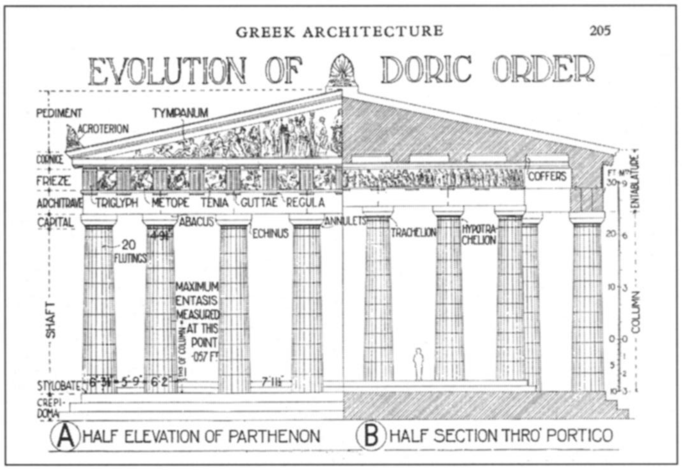

Fig. 1. "Evolution of Doric Order" reference drawing from *Sir Bannister Fletcher's A History of Architecture*, revised 18th ed. (New York: Charles Scribner's Sons, 1975).

Fig. 2. West elevation, 2002, completed restoration. Photograph by Gary Layda, courtesy of the City of Nashville.

attached to the entablature above the architrave.

Born in New York in 1881, John J. Earley was the son of Irish immigrants. He became a fifth-generation sculptor, who worked in stone. After his father James' death in 1906, Earley stayed on in New York to continue the work of the Earley Studio. Together with Basil Gordon Taylor, his lifelong business partner, Earley transformed the shop into a highly productive studio in the twentieth-century medium of concrete. With a background in the stone-carving trade, Earley's work was rooted in the tradition of medieval crafts guilds. It built upon the respect for hand-craftsmanship nurtured in this country by the Arts and Crafts movement in the late nineteenth century.[3]

Remarkably, the 1925 Nashville Parthenon is an exact replica of the original in Athens, matching its form, dimensions, and coloring. A review of the extensive literature about the 1925 Nashville Parthenon revealed that the extant marble from the Acropolis was color-matched by selecting warm-colored aggregates used in the mix that "give[s] a surface of admirable texture and of rich, even tone."[4] To achieve the brownish yellow color similar to what he assumed to be the oxylate surface of the marble at the Acropolis, Earley used a mixture of crushed Potomac River gravel of brownish yellow hue, along with white and pink quartz and a few particles of a dark, brick-red ceramic. To ensure uniformity in the mix, enough aggregate was prepared for the whole job, plus a supply for future maintenance.

Investigation, Testing, and Documentation

Gradual deterioration of the Parthenon had been documented and monitored for years before this project was funded and a professional team assembled to properly address the building's condition. The project team was comprised of Quinn Evans I Architects, which has special expertise in the restoration of historic structures; Tracy Coffing, architectural conservator, who has extensive experience in concrete and outdoor sculpture restoration; and Ross Bryan Associates, consulting engineers, which specialize in designing concrete structural repairs. The professional team precisely mapped, quantified, and evaluated conditions to develop a set of treatments that would address the deterioration at the roof, pediments, entablatures, and walls of the building. Repairs were executed in phases under the construction management of the Orion Building Corporation, supported by Western Waterproofing, which installed the replicated pieces and performed the repairs and restoration treatments. All laboratory testing of materials, both existing and proposed, was performed by Erlin, Hime Associates.[5]

The decision to replicate missing historic features was based on the mandate set by Metropolitan Parks and Recreation of Nashville to renew and restore the building to its 1931 appearance, the date of the completion of the reconstruction using the Earley concrete casting method. The amount of material that was replaced was based on the treatment option outlined in the "Exterior Restoration Study of The Parthenon" completed by the team in 1993, which recommended restoring the pediments and entablatures to their original appearance.[6] This overall restoration approach is consistent with the Secretary of the Interior's Standards for the Treatment of Historic Properties, which defines restoration, in part, as: "the act or process of accurately depicting the form, features, and character of a property as it appeared at a particular period of time..."[7] The building was generally in poor condition and created a public risk from the continuing failure and loss of material; in addition, the design integrity was severely compromised and no longer able to convey its educational and historic message inherent to this local landmark. For all these reasons, restoration was the recommended approach to treatment. Deciding on the extent of replacement and the means of reproducing the historic features are presented in this paper.

Pre-rehabilitation investigation. The significance of Earley's design is that he created a mix that was strong, yet achieved the desired appearance of the exposed aggregate. Uniformity in appearance was the primary aesthetic objective accomplished by step, or gap, grading of the aggregate.[8]

The practically universal formula for structural concrete in the United States in the second decade of the twentieth century was a 1:2:4 mix: one part cement to two parts sand and four parts gravel, measured by volume.[9] This formula assumed a uniformly graded composition. Earley experimented in his studio with a proportion of aggregates of all one size and just enough sand and cement to fill the spaces between them, and he hit upon a maximum particle diameter ratio of 10:1. This gave the desired uniformity and exposed the greatest face area of the pebble aggregate, but the mix was modified and designed for requirements of each specific project. The sand and cement created a neutral paste, with the pebble color giving the overall color to the finished surface. No other additives are mentioned in Earley's writings or were commonly used by his studio.

Unfortunately, all of the Earley Studio records were lost in a fire at his plant in the 1950s, leaving only his writings and other published sources for technical details about his process, mixes, and colors. The Earley mix has been the subject of much speculation, and the design mix specific to each job can be confirmed only through modern laboratory analysis.

Materials testing. Initially, 11 concrete pieces, selected to represent the diversity of conditions on the Parthenon, were submitted to Erlin, Hime Associates, Construction Material Consultants, for study and analysis. Some of the pieces were roof tiles and chunks that had broken loose from the building, and some were cores taken from sound material in the pediment sculptures and the naos walls. In addition, roof tiles that had been exposed to weathering and those that had been in storage (unexposed) were analyzed for both the face mix and the body. Also tested were colored aggregate pieces from the regula and the Greek key elements. Virtually every type of concrete element that was ultimately treated was subjected to laboratory testing, including numerous cores from the pediment and metope sculptures. Tests performed included petrography (ASTM C 876), chloride content (ASTM C 1152), compressive strength (ASTM C 39), and freeze-thaw (ASTM C 666).[10]

Fig. 3. Erecthonius and Hermes from the west pediment prior to 1925, being modeled in clay for recasting. The figure of Athena to the right of Hermes is thought to be salvaged from the 1897 version and stands ready for repairs. Photograph courtesy of the Parthenon.

The petrographic studies indicated the types of coarse and fine aggregates, their color and size, and evidence of trace amounts of other rock types. Coarse aggregate taken from buff-colored areas of the building and statuary revealed a combination of crushed and natural siliceous gravel of ¼-inch size with major amounts of quartz, moderate amounts of chert and sandstone, and minor amounts of diorite and granite. Most particles were dark buff and light gray, hard and angular. Fine aggregate from these same areas was a combination of natural and crushed siliceous sand composed mainly of light gray and light buff-colored quartz. Feldspar occurs as a trace component.

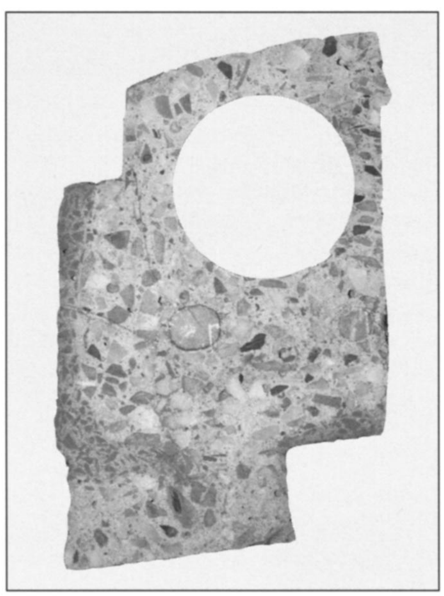

Fig. 4. Cross-section of regula piece with mutule. The hole is where a core sample was taken for laboratory testing. The step-graded buff mix is visible in the section, as is the steel bar reinforcing. A dark line around the steel bar indicates slight corrosion, also indicated by hairline cracks radiating outward from the bar. Courtesy of Wiss, Janney, Elstner Associates, Inc.

The coarse and fine aggregates were set in a beige-colored cement matrix of Portland cement and minute amounts of pigment. The coarse aggregates are exposed and gap graded. Typically, the samples were found to have high cement content (between 6 and 7.5 bags per cubic yard of concrete) and a moderately low water-cement ratio (about 0.44 to 0.48). All samples were non-air entrained and contained only about 1 to 2.5 percent of entrapped air, inadequate for protection against cyclic freeze-thaw damage. Because of the great variety in the samples that were tested, an exact mix design was not determined in the analysis, focusing primarily on identification of the components and their performance (Fig. 4).

Chloride levels (<0.007 at most samples) in the analyzed specimens were considered low. Compressive strengths ranged from 6,320 pounds per square inch (psi) to 9,140 psi for the face mix and the body mix respectively. Most original pieces were cast with a conventional concrete mix as the body or base material and recast with the Earley mix for the visible outer 1-2 inches. Visual observations of the freeze-thaw test results showed slight deterioration after 100 cycles up to severe cracking and falling apart when the cycles were discontinued at 300 cycles.

Documenting the scope of work. Photographs were taken of all of the sculptural elements at both pediments and at each of the metope panels to illustrate repairs to the individual sculptures. The scanned photos were supported with notations and detail references on standard-sized sheets for consistency in layout and handling of the phased drawing packages. Specifications were adapted to the same format and sheet size.

Drawings supplemented the photographs for specific and general repairs. Only one original 1925 drawing of the upper level plan was found. It was used to develop representative drawings of the plaza level plan, roof plan, reflective ceiling plan of the soffit, and exterior elevation drawings. Based on sketches of existing conditions and the recommended concept for repairs, details illustrated attachment of the reproduced elements, including methods of introducing new stainless-steel reinforcing within each casting (Fig. 5).

Specifications were customized for the specific materials needed to reproduce the Earley mix. The mix was designed to match existing conditions and to describe the specific treatments for cleaning and restoration of the concrete. In all, there were four issues critical to matching a wide variety of existing conditions:

1. mix design (buff, blue, and red colors of both aggregate and matrix)
2. casting methods (large sculptures and applied trim)
3. artistry (sculptural and surface texture)
4. installation methods (cold joints, reinforcement, and anchors)

The specifications were cross-coordinated to ensure consistency of mix designs and sources of materials, even when separate sub-contractors were producing the pieces in multiple phases. All of the pre-cast applied-trim elements were produced by one sub-contractor, J. B. and Sons, Inc., of Hackettstown, New Jersey. All of the pediment and metope sculptural pieces were produced by George Kreier, Jr., Inc. of Philadelphia, Pennsylvania. The roof tiles, ridge cap pieces, and decorative acroteria were produced by a cast-stone manufacturer, Architectural Art Stone of Kansas City, Missouri. Cast-in-place repairs at the raking cornice and eaves were carried out on site by Western Waterproofing.

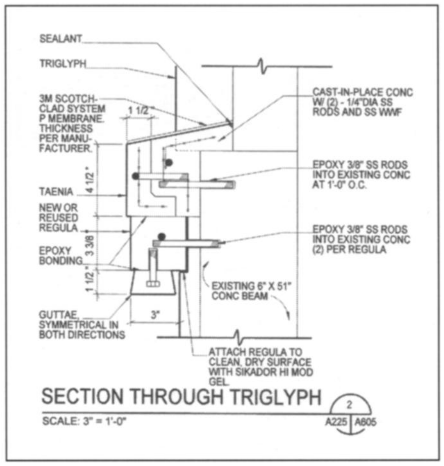

Fig. 5. Section through triglyph shows typical anchoring of pre-cast elements. Drawing by Quinn Evans | Architects.

Mix Design

The buff-colored concrete mix design generally used for all of the restoration work at the Nashville Parthenon is a 1:1:3 mix of one part cement to one part sand and three parts pebble aggregate, measured by weight. The specifications described the mix design by measurements per 94 pound sack of cement as follows:

White cement, Federal White Cement Co., Type I ASTM C150	94 lbs.
Nutty pebble, size A, Southern Aggregate, Staley, N.C., ASTM C33	47 lbs.
Brown pebble, Southern Aggregate, Staley, N.C., Williamstown, N.J.	235 lbs.
Bar sand, JDM Materials, Williamstown, N.J.	94 lbs.
Yellow pigment HC31, Hamburger Color Company, King of Prussia, Pa.	94 grams
Black pigment 8H90902, Hamburger Color Company, King of Prussia, Pa.	47 grams
Potable water	375 fl. ozs.
Acrylic polymer bonding additive, MB Acryl Set	125 fl. ozs.
Air entrainment, Master Builders, MB-VE90, quantity to achieve air content of	7% ±1%
High-range water reducer, Master Builders, MB 440N	-10 to 25 oz/cwt.

Variations were approved for specific applications in order to achieve a visual match to adjacent areas, but generally remained within these proportions. Testing confirmed that total air content was at 7 percent ± 1 percent, that water absorption did not exceed 6 percent by weight, and compressive strength reached 5,000 psi minimum at 10 days (compression tests performed in accordance with ASTM C39). Elements that were produced from batches not reaching these criteria were discarded. Master Builders (MB) products were added to achieve these performance criteria and were omitted when not needed.

Crushed ceramic tiles in two graded sizes were used to achieve the colored detail in the blue and red pre-cast pieces. The other elements of the mix were

Fig. 6. J. B. and Sons craftsperson delicately lays or "butters" the red and blue colored grout into the mold. Photograph by the author.

generally the same as for the buff mix, although pigments were omitted, and the Acryl Set was increased for the tiny details to 1:1 with water. Acryl Set was added to the mix design to provide better adhesion of the pebbles into the matrix and to increase the air content. It did not affect pourability, but did improve the workability of the mixes and weather-resistance of the finished castings. Pigment was added to soften the effect of the white cement and create as close a match as possible to the extant material adjacent to the restoration work areas. Since the original formulas are lost, the intent was to match the weathered appearance of the original Earley mix with the new material.

Air entrainment was typically used for the pre-cast replication but reduced or eliminated when a high slump or flowable mix was required, as for the statuary elements. The high slump was achieved with the MB 440N high-range water reducer, and, when used in conjunction with the water reducer and air entrainment, Acryl Set caused foaming of the mix.

Following all installations and repairs, the entire building was cleaned with a mildly acidic cleaner containing no hydrochloric, hydrofluoric, or sulfuric acids, and no chlorine bleaches or caustic soda.[11] Pre-testing all of the specified products ensured safety and effectiveness of the treatment in achieving a match between extant and replicated materials.

The repaired and cleaned surfaces were treated with a concrete corrosion inhibitor and a water repellent.[12] An opaque traffic coating was installed on the ledges of the pediment and the taenia to minimize water intrusion.[13] Sealants were used at selected joints and embedded with the pebble aggregates to match the adjacent concrete surface.[14] Nylon netting was stretched across the sculptural panels of the Doric frieze and the pediments to eliminate pigeon roosting and soiling of the restored building; netting was hooked onto stainless-steel cables and fastened with eye wire standoff pins into the concrete.[15] All of the materials for these additional treatments were tested with mock-up installations to ensure that they were effective and that they resulted in no harm to the building.

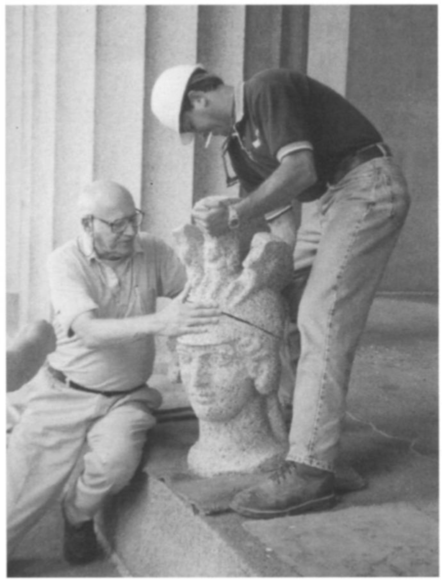

Fig. 7. Dr. Kreier and Ken McAbee from Western Waterproofing test the mating of two pieces of the Athena sculpture before inserting anchoring steel and lifting her into position. Photograph by the author.

Casting Methods

Casting of both the large sculptural pieces and the smaller applied-trim pieces was essentially the same. The primary difference was the fabrication method, in that the sculptural pieces were one-of-a-kind and the trim pieces were mass-produced, as were the roof tiles. The sculpture and trim casting was carried out by two different sub-contractors in two off-site locations and delivered to the site for final approval prior to installation. To encourage consistency and quality in the produced elements, the owner's representative, the constructors, and the project team visited the fabrication studios.

The first stop was the studio of Dr. George Kreier in Philadelphia. While the intent was not to approve specific pieces in the studio, the project team did approve Dr. Kreier's methods, sample coupons, reinforcement methods, and the general artistic merit of the castings. This allowed him to continue fabrication on an aggressive schedule, and most pieces were approved when they were brought to the site. The project team continued to review batch reports for each piece to ensure overall quality of the concrete mix. Very large pieces were cast hollow, a method which was determined to have been used by Earley, to lessen the weight on the building. Hollow casting made installation of the larger pieces much easier.

The next stop was the studio of J. B. and Sons in central New Jersey. An efficient assembly line had been set up to produce the multiple trim pieces. Original elements had been salvaged to serve as models, and new molds were created for each shape. Stainless-steel mesh and threaded rods were custom fabricated to reinforce each shape and inserted in the molds as the pieces were cast. Separate grout mixes for the colored details were buttered into the mold and vibrated for two to three seconds (Fig. 6). The molds were set aside for 45 minutes, and then the buff-colored mix was poured to fill the mold flush with the top edge. After inserting the pre-formed reinforcement grid, the filled mold was vibrated for two to three minutes to ensure there were no voids and to release air bubbles, and then set aside for two days before removing the form. The individual castings were wrapped in burlap and cured for an additional seven days, then lightly etched with hydrochloric acid and brushed to expose the aggregate. Since the pieces were small and had cured for seven days, J. B. and Sons did not dilute the acid; it was applied and immediately rinsed, and repeated if necessary. Finished pieces were shipped to the site in batches for inspection and installation. Pieces having a deeper etch than required were rejected.

Artistry

Like the original Pentelic marble sculptures for the Parthenon in Athens, the sculptures for the pediment of the Nashville Parthenon were created by artists. To restore the sculptural concrete elements, artists were enlisted to prepare the clay models in situ, from which reinforced molds were created. The restoration sculptors worked with respect for the artwork of the original artists, and with just as much attention to historic precedence. The prepared molds were transported to Philadelphia, where Dr. Kreier and his crew prepared test plaster castings, tested the aggregate casting mix, and executed the cast-concrete final pieces. They were delivered to the site in batches for review and approval prior to installation (Fig. 7). Sev-

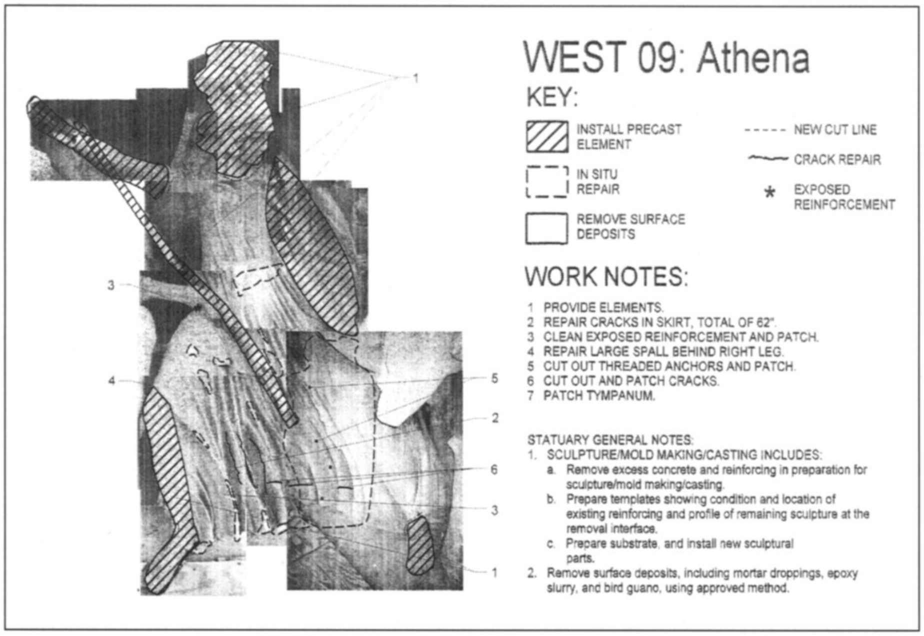

Fig. 8. A drawing of Athena in the restoration of the west pediment sculpture illustrates repairs and the extent of replacement elements. Drawing by Quinn Evans | Architects.

eral freelance artists remained on the job for the entire project as part of the construction team.

Installation

After receiving visual and technical approval, each piece had to be attached securely to the building using a method that did not compromise the aesthetic of the original design. The drawings indicated the intended location of the cut line where each new sculpture piece would be mated to sound extant material (Fig. 8). Sound existing steel was retained, but new reinforcing, a combination of welded stainless-steel mesh and threaded rods, was added. Sketches were used to describe the unique conditions for each piece and its eccentric loading that could support the weight of the new cast-concrete elements. The approved concept for inserting the reinforcement was executed in the field and installed by the general contractor, Western Waterproofing.

Scope of Work

Providing access to the work areas was a major investment that accommodated the continuing operation of the Parthenon Museum, public use of the surrounding Centennial Park, and the contractors' safe and efficient construction work. Each phase of work had specific requirements that were handled in sequence.

Scaffolding went up in 1994 and was not removed until 2001. At the east and west ends of the building, fixed scaffolding had multiple work levels beginning at the column capitals up to the peak of the gable ends. A stair tower at each end provided access to the work areas; it was also possible to walk across the rooftop from one side of the building to the other. For work at the long sides of the building, long rails were set in place at grade, and rolling scaffolding was moved incrementally along the sides as work progressed. Because it was quicker and more portable, occasionally a motorized lift was also used for access to inspect conditions or perform specific tasks.

Phase I: roof tiles. Work was undertaken in phases to correlate with budget allocations and in logical sequence as the work moved around the exterior of the building. Elements that either created risk or could be salvaged were removed and placed in storage to be evaluated later for modeling and reproduction. Starting with the roof, this first phase was designed to eliminate leaking and to restore the architectural integrity and water resistance of the original design.

Drawings illustrated treatment options and defined the scope of work. Mock-ups were erected to test the flashing details in situ at both the curved corona forming the back side of the rake of the roof slope and at the built-in gutter. Sheet metal was extended over the eave edge to improve the flow of rainwater off the roof and away from the restored detailed castings.

The old tiles were severely eroded and suffered extensive loss of surface aggregate, due primarily to carbonation of the original mix and corrosion of the internal ferrous reinforcing. All of the roof tiles were replaced with new pre-cast concrete tiles matching the original profile and size but with a slightly modified concrete mix that included fiber reinforcing.[16] The aggregate in the mix was selected to match the original Potomac River nutty pebble, and the tile forms were modeled to exactly match the original design. The tiles were cast in plastic molds, which were first sprayed with a latex surface retarder. A superplasticized mix with a 9-inch slump was poured into the molds and consolidated on a vibrating table. The following day the pieces were stripped of their molds, and the retarded surface was pressure-washed with water to expose the nutty pebble aggregate. After curing, the tiles were installed like shingles on the prepared roof substrate.

Phase II: prototype casting methods. Phase II tested the procedures and materials that would go into the contract documents for bidding and performing the restoration. This step was crucial to assuring quality in the finished work and to fairness in the bidding and execution of specified procedures. Specifications created for this phase provided a guideline of acceptable procedures and materials, which would go into the subsequent document packages.

Innumerable test coupons were prepared to achieve a mix with a close visual match to extant concrete. Three colors, based on those used in the 1925 replica were to be matched: buff used throughout the building and for all of the sculptural pieces; red for detail, the flat back of the metope panels, and the tympanum wall; and blue for other miscellaneous details. This prototype phase determined the accepted mix design and identified sources of the aggregates.

Fig. 9. Cutaway view of taenia, regula, and guttae shows the "before" condition of the decorative surface and corrosion of the embedded steel reinforcing. Photograph by the author.

Fig. 10. Mock-up of taenia, regula, and guttae cast-in-place and pre-cast concrete repairs. This work was executed under the triglyph and metope panels around the entire perimeter of the building. Photograph by the author.

Mock-ups were created at selected metope panels for casting replacement pieces, judging both the color match of the mix and the sculptural quality of the forms. Repair methods were tested for the entablature pieces below the metopes and triglyphs, including the taenia, regula and guttae, to ensure a satisfactory method of reinforcing the elements and anchoring them to the wall (Figs. 9 and 10). Replication and reattachment of the mutule (soffit) panels was particularly difficult because of their complex form and the lack of bearing for the heavy panels on the existing structure. Replication of the pediment sculptures required more than knowledge of materials and craftsmanship; it also required an artistic interpretation of the element being replicated.

Phase III: east pediment and entablature. Work at the east elevation was the next step after approval of the prototype casting methods. At this time, the scaffolding became a permanent fixture and remained in place until the entire project was complete. Documented quantities of the required work formed the basis for contractor pricing. The architects for the project identified each patch and length of crack to be repaired. The documents also indicated the exact pieces and joint lines for replacing the sculptural elements of the pediments and metopes. The documented quantities were relatively accurate for the execution, but occasionally a more aggressive replacement was warranted to ensure removal of corroded embedded reinforcement of the portions to remain.

Flat sections of the entablature were originally poured in place over a concrete substrate. Loss of adhesion or water intrusion had caused isolated delamination of the decorative surface. Where inspection detected areas that were hollow-sounding, and therefore delaminated from the substrate, they were pinned with stainless-steel helix anchors and injected with epoxy to stabilize the composite surface; patch holes were filled with the buff patch mix to blend with the aggregate surface.

Robert Armbruster, an expert on the work of John J. Earley, participated in the east elevation repair work. He consulted on the proposed casting mix and provided the team of sculptors who did the clay modeling for the east pediment sculptures. Dr. Kreier's studio prepared the molds and executed all of the castings.

Phase IV: west pediment and west, north, and south entablature. Work continued around the building without interruption and with the continuation of the same construction team, except that Dr. Kreier's crew performed all of the modeling and reproduction of the sculptural pieces. As a final tour de force, Dr. Kreier produced the floral and gryphon acroteria for the roof. The extant gryphons from the Parthenon's four corners were beyond use but were very important for modeling the new pieces. The biggest challenge was figuring out how to cast and assemble the large pieces. After completing the modeling in clay, the large forms were cut into smaller sections, which were cast separately, then reassembled with reinforcing into one piece.

Phase V: naos walls, steps, and plaza repair. In addition to repair of the decorative and cast elements, repairs were required at the flat surfaces of the naos walls, the steps, and the front plaza. The original construction materials were similar for these flat surface areas and therefore required the same specified repairs. Shrinkage cracks and incompatible old sealant repairs in the naos walls were cut out and grouted with the Earley mix, then brushed to blend with the extant sound material. Areas of the steps were rebuilt using the Earley mix poured over repairs to the concrete substrate. After finishing, the surface was acid washed and brushed to expose the aggregate to match sound adjacent material. Sealant was installed in the plaza joints, but where sealant was used for crack repairs, pebble aggregate was pushed into the sealant to blend with the Earley mix.

Phase VI: soffit decorative painting. The only non-concrete material of the Parthenon exterior is the plaster soffit inside the peristyle. This protected area was very likely a portion of the original 1897 construction that had been preserved and therefore was not reproduced in the Earley concrete. The area had a poorly executed decorative paint scheme that was flaking badly. Also, pigeons had roosted along the plaster ledge of the entablature and soiled these ledges and the areas below where visitors to the site would be walking. After researching information on the original colors used at both the Athens and the Nashville Parthenon structures, the architects recommended a color scheme for the restoration. It was not possible to use any chemical paint remover because fumes inside the building made people ill. Therefore, duct tape was used to pull off scored, unsound paint to prepare the surface for application of new acrylic paint. [17]

Black nylon mesh was stretched across the underside of the soffit to prevent pigeons from roosting; the mesh is almost invisible, and the rich new colors are an important decorative feature of the finished restoration.

Conclusion

Completion of the project was celebrated on New Year's Eve 2001, when the new pre-cast gryphon acroteria were "flown in" by crane and steel cables to symbolically top off the project. Replication of the John J. Earley concrete mix was technically and aesthetically successful because of thorough laboratory analysis and prototype testing of materials and batch mixes. In a final assessment, the aesthetic evaluation may out-weigh the specific formulaic match, as adjustments were necessary for the various repairs and replacements to visually match the adjacent sound materials of the Earley project, but without compromising the integrity of the mix design. Many of the materials have been stockpiled, e.g. the nutty pebble aggregate and surplus castings, for future repairs and modifications to the building, and a detailed record of procedures and approved installations is available on-site for future reference and study.

ILENE R. TYLER, FAIA, FAPT, is Director of Preservation at Quinn Evans | Architects in Ann Arbor, Michigan. A graduate of the University of Michigan, she also teaches preservation technology at Eastern Michigan University. From 1995–99, she served on the APT Board of Directors.

Notes

1. Wilbur F. Creighton. *The Parthenon in Nashville.* (Nashville: Wilbur F. Creighton, 1989, revised edition, 1991), 19.

2. Frederick W. Cron. *The Man Who Made Concrete Beautiful.* (Ft. Collins, Co.: Centennial Publications, 1977), 32. Frederick W. Cron wrote this biography of John Joseph Earley to trace the development of the "Earley Process," which he perceived led to a revolution in architecture. In the preface he explains the loss of the Earley Studio's records in a fire at his studio in the 1950s, causing him to rely on Earley's writings and various proceedings from the American Concrete Institute and other published sources. While his motivation is not explained, it is clear that he had a personal interest in and understanding of the Earley Process and appreciated the significance of the projects completed under the direction of John J. Earley and his partner, Basil Taylor. While Cron provided extensive detail about Earley's history and projects, he did not find or describe any test data on the materials and their performance.

3. Cron, 6.

4. H. B. Schermerhorn "The Parthenon of Athens and its Reproduction in the United States. Fourth Installment of a Series Descriptive of a Remarkable Work," *The Parthenon Journal of the Incorporated Association of Architects and Surveyors.* (London: Wilbraham Place 1931), 182. This series of five articles summarizes the history of the Athens Parthenon and compares it to the Nashville reproduction. The first four were written by Dr. H. B. Schermerhorn, and the final installment was written by Russell E. Hart, architect of the reconstruction of the Nashville Parthenon. These accounts provide a historical perspective on the knowledge of the Athens Parthenon and how that knowledge was used by the architect to design the Nashville reproduction. These articles substantiate the research undertaken at the time of the reproduction and the extent to which the architect and sculptors strived to make their reproduction as accurate as possible. The article by Hart, in particular, describes the extent to which the 1896 materials were salvaged and incorporated into the reconstruction and how the studio of John J. Earley collaborated with Hart, the sculptors, and the general contractor, Foster and Creighton Company.

5. Erlin, Hime Associates, a division of Wiss, Janney, Elstner Associates, Inc. for over 20 years, discontinued use of the Erlin, Hime name in 1998.

6. David S. Evans and Tracy Coffing. *Exterior Restoration Study of The Parthenon.* (Quinn Evans | Architects, April 1994), 37.

7. National Park Service. *Secretary of the Interior's Standards for the Treatment of Historic Properties*, 1992. Restoration is defined as "the act or process of accurately depicting the form, features, and character of a property as it appeared at a particular period of time by means of the removal of features from other periods in its history and reconstruction of missing features from the restoration period." These standards go on to require work that is done to stabilize, consolidate, and conserve materials to be physically and visually compatible, identifiable upon close inspection, and properly documented for future research. Deteriorated features shall be repaired rather than replaced. Replacement features shall match the old in design, color, texture, and, where possible, materials. Replacement features shall also be substantiated by documentary and physical evidence. Chemical and physical treatments shall be undertaken using the gentlest means possible. The standards that define "restoration" as an approach to treatment apply to the work at the Nashville Parthenon.

8. Cron, 11. Cron's biography diagrammed and described the graded mix development. Although today it may be more commonly referred to as "gap-grading," Cron described the particle sizes in the design mix as "step graded."

9. Cron, 11.

10. Erlin, Hime Associates. *Studies of Concrete for Board of Parks and Recreation, Nashville, Tennessee.* WJE No. 938472, March 11, 1994.

11. Sure Klean Light Duty Restoration Cleaner, manufactured by ProSoCo, Inc., was used for general cleaning of the Parthenon exterior concrete. This product contains <1% of hydroxy-acetic acid, sulfamic acid, and hydrofluoric acid. Additional ProSoCo products were used for special treatments and spot cleaning.

12. Sika Ferrogard 903 Corrosion Inhibitor, manufactured by Sika, Inc., was applied over all exterior concrete surfaces. It was determined that the depth of penetration reached 1 inch, 30-60 days after being coated. Reinforcing is typically at 1½ inch depth, but the manufacturer expected the material to achieve further penetration with time. Treated surfaces were also visually inspected, and, although there was an initial darkening of the concrete surface, it gradually faded to match the untreated appearance. There was no effect on the permeability of the original concrete. The team felt this application would be beneficial for the original concrete that had lost its protective alkalinity due to extensive carbonation.

Weather Seal Siloxane WB Concentrate, manufactured by ProSoCo, Inc., was used for a water-repellent finish system over all exposed exterior concrete. Testing on concrete designated for replacement or on new concrete samples visually confirmed that any initial darkening quickly dissipated. The water-repellent, which did not alter the vapor permeability of the concrete was used because: (1) it would provide some protection from moisture-related deterioration of existing concrete; (2) it would provide general protection from moisture-related deterioration on the sculptural elements that were not easily accessible for regular maintenance and repairs; and (3) it would help discourage the rapid regeneration of biological growth on the concrete. The water repellent was applied over other repairs and treatments so that the completed structure would have a consistent appearance.

13. 3M Traffic Topping Scotch-Clad Brand Deck Coating System "P" was applied over the corrosion inhibitor as a finish treatment on horizontal surfaces not visible from the ground. The color was specified to match the buff color of the adjacent concrete mix.

14. Multicomponent Nonsag Urethane Sealants (both Sikaflex – 2c NS and Tremco Dymeric 511) were used in compliance with ASTM C 1193, except where aggregate was embedded to match adjacent surfaces.

15. Bird Barrier America, Inc. provided black ¾-inch StealthNet, stainless-steel cabling and eye wire stand-offs. Installation was stretched around all projections of the sculptural figures and panels as needed to prohibit contact of the netting and to prevent birds from roosting.

16. NYCON Inc. Caprolan-RC fibers, 100% virgin nylon monofilaments.

17. Evergreene Painting Studios, Inc. completed the decorative paint scheme for the exterior soffit.