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SECRETS OF JOHN J. EARLEY'S MOSAIC CONCRETE ON THE BAHA'I TEMPLE

by Robert F. Armbruster

ABSTRACT

Synopsis: What were John J. Earley's secrets? None of his competitors could match the impeccable quality, distinctive appearance and seemingly impossible complexity of Earley Studio's exposed aggregate concrete. For the Baha'i House of Worship, in Wilmette, Illinois, Earley produced architectural precast concrete panels. The restoration of the Baha'i Temple required extensive research, testing and experimentation to match John Earley's original work. As the restoration team gained experience, the finer details of Earley Studio's process became clear and some of Earley's secrets were revealed. This article discusses the crushing, screening and gradation of aggregates; mixture proportions and additives; preparation of molds, form retarders, placement and consolidation techniques; finishing and exposure of aggregate; and how assemblies of precast components and cast in place concrete can produce seamless results.

Keywords: Baha'i Temple; John Earley; exposed aggregate; mosaic concrete; precast

A video of the full presentation with 65 slide images is available on Youtube:

Secrets of John Earley's Mosaic Concrete on the Baha'i Temple

https://www.youtube.com/watch?v=buMySF2mHyE

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SECRETS OF JOHN J. EARLEY'S MOSAIC CONCRETE ON THE BAHA'I TEMPLE

INTRODUCTION

"Can you build this temple with your concrete material?" The anxious architect posed his question to architectural sculptor John Joseph Earley in August of 1920. The plaster model in the architect's photograph was the most exotically beautiful building that Earley had ever seen.1 Although Earley could not answer "yes" during that first encounter, he was captivated by the idea. It was the beginning of a lifelong friendship between the architect and the sculptor. It was the beginning of the Baha'i Temple project for John Earley.

The architect, Louis Bourgeois, showed Earley a photograph of his model for the Baha'i House of Worship in Wilmette, Illinois, just north of Chicago. For John Earley to produce the Temple's cladding over the next thirty years, he would need every innovation he had already developed and more. To finish the Temple's dome, Earley would create some of the first architectural precast concrete panels.

Although Earley eloquently described his projects in twelve papers for the *American Concrete Institute* and numerous trade publications, he was an astute business man who withheld critical details of his materials and his process. None of his competitors could match the impeccable quality, distinctive appearance and seemingly impossible complexity of Earley Studio's exposed aggregate concrete. What were Earley's secrets?

Restoration projects on the Baha'i Temple between 1987 and 2010 required extensive research, testing and experimentation to create repairs that match John Earley's original work. Basil Taylor's shop drawings for the Baha'i Temple clearly convey his strategy for precast components and assembly.[2] Earley's progress photos of production and installation often reveal the Studio's methods and materials.[3] Earley Studio's internal documents confirm John Earley's published descriptions. The Studio's test reports of their "proprietary" mixtures were cloaked in a shield of non-disclosure to their clients, yet the test reports provide quantitative information that can be interpreted to reverse-engineer the concrete mixture design.[4]

As the restoration team gained experience producing exposed aggregate concrete components for the Baha'i Temple, long-kept secrets of the Earley process were revealed.

APPLYING TRADITIONAL TECHNIQUES TO CONCRETE

John Earley began to use Portland cement by adapting traditional techniques employed for other architectural materials. Earley was trained as an architectural sculptor in the studio of his father, James Earley. Upon his father's death in 1906, John took over the studio at the age of twenty-five.[5] The studio worked with carved stone, clay, lime and gypsum plaster. It was a natural transition to cement stucco and concrete.

As architectural sculptors, Earley's craftsmen quickly shifted their plaster based modeling and molding to concrete. Captivated by the idea that a mosaic might be produced in concrete materials, they transferred their experience with traditional tesserae mosaics to concrete mosaics.[6] The Studio brushed back the mortar to expose the pebbles in this new material that was cast within forms.[7]

Yet Earley found that concrete had unique properties which required modified techniques.[8] Applying cement-based stucco proved to be very different from the art of gypsum plastering.[9] Methods the Studio routinely used with clay and gypsum based materials were not effective when applied to concrete. Before it hardens, wet concrete lacks the stability found in the gypsum or clay materials. Solids separate. Water bleeds. Voids form. Unattractive castings are the result. After hardening, the surface of the solid concrete is extremely difficult to refine with additional carving or polishing.

EARLEY EXPLORES CONCRETE

John Earley approached concrete as a craftsman. Earley's experiments and tests were based upon his craftsman's sense for the materials and their practical behavior during production operations. While attentive to concrete's strength, he was far more concerned with the workability of the mix and with the finished surface where he treated the aggregate as spots of color.[10] While maintaining consistent quality among his finished products, Earley recognized that the procedures for working with this new material must be designed for each application rather than being locked into rigid formulas.[11]

Earley then explored the special aspects of concrete that called for unprecedented methods. Instead of handling cement stucco as traditional plaster they began to treat it as miniature concrete. The artisans finished concrete by wire brushing the surface and washing it with acid to produce permanently colored surfaces. The Studio also abandoned the traditional concrete mixture proportions, the sequence for batching the ingredients and the time of mixing.[12] They used only two sizes of aggregate instead of a continuous range of sizes. They placed the wet concrete as if it was an artist's medium rather than a lumpy mass dumped into a box.[13] Most importantly, they treated concrete very differently during each of its two states – first, as a plastic substance when wet and, next, as a solid material after the time of set.

Earley recognized that less force is needed to handle and shape a plastic mass than a solid mass. Less force meant less cost. Earley concluded that economy and adaptability depended upon his ability to manipulate the plastic qualities of this material.[14] He began to change the amount of water within the concrete during its plastic state. "Convinced that 'mixing water' means more to a craftsmen than to an engineer", Earley concentrated his effort on the control of water during the initial hours of the material's life.[15] Earley's production techniques relied upon mastering this phase of concrete. The same principles were also critical in his methods for cement stucco.[16] Earley took full advantage of his "freedom to do anything I might reasonably wish to do with Portland Cement in the first twelve hours after wetting it."[17]

John Earley also investigated concrete's key ingredient, the aggregate particle. He viewed the aggregate in concrete as the skeletal structure that prevented changes in volume, settlement and segregation.[18] He also relied upon the aggregate to determine the final appearance in color and texture.[19]

EARLEY INNOVATES TO MEET NEW CHALLENGES

When new projects pushed Earley Studio beyond the limits of what they had already accomplished, Earley's craftsmen developed fresh innovations.[20] As a plaster and stucco contractor, Earley Studio was asked in 1911 to install test panels for the Bureau of Standards to evaluate cement stucco. In 1916 John Earley was asked to prepare all of the samples for a second round of tests and to personally sit on the Committee evaluating the results.[21] Earley experimented and discovered how to control the water during critical stages in the process of applying cement stucco. This breakthrough was fundamental to Earley's later development of architectural concrete. Earley continued to work with J. C. Pearson of the Bureau of Standards in a third and fourth series of tests. Defying conventions, Earley and Pearson treated the stucco as a miniature concrete and determined what sizes of aggregate and sand provided the closest packing and the greatest capillary movement of water.[22]

In 1916, for Meridian Hill Park in Washington, DC, Earley created exposed aggregate concrete[23] with a two-step gap grading of aggregates for a refined appearance, a process protected by Earley's second patent.[24] After casting the concrete into molds, Earley extracted its excess water. This permitted removal of the molds and exposure of the aggregate at the most opportune time.[25] Earley Studio continued to work with contractor Chas. H. Tompkins Co. to complete later portions of the Park.[26]

When building the East Potomac Park Field House in 1920, Earley Studio combined cast-in-place concrete, large precast components, thin precast elements and hand-applied stucco to economically create a uniform architectural finish.[27] To eliminate the tedious job of touching up the plaster molds after each casting of concrete, Earley started to use a thin metal lining within the molds to make them more durable. These linings were so effective that all of the column capitals were cast in one set of molds.[28] Earley received his third patent for molds.[29]

THE BAHA'IS SEARCH FOR A NEW MATERIAL

Just four months before visiting John Earley in 1920, architect Louis Bourgeois won an international competition for the design of the first Baha'i House of Worship in the Western Hemisphere. To prepare his entry for the competition, Bourgeois spent two years translating his vision of a "Temple of light" into a 10 ft. (3 m) tall plaster model that could adequately convey his dream.[30] Bourgeois had conceived a gigantic, open worship space with light streaming in through curving, filagreed walls and through a lace-like dome. The thin dome and high walls were covered in elaborate ornamental relief, penetrated by tens of thousands of openings. The Baha'i community enthusiastically selected Bourgeois' spectacular design concept. Unfortunately, neither Bourgeois, nor any of the many distinguished architects and engineers who examined his design, knew of a material that could be used to build the architectural cladding.

The Baha'i leadership appointed a committee of Bourgeois and notable architects and engineers to search for suitable material for the Temple.[31] The Materials Committee was chaired by Major Henry Burt, the chief structural engineer for Holabird and Roche. Burt had supervised construction for the Palmer House Hotel, the Tribune Tower and Soldier's Field stadium. The Baha'i leadership had selected him to design and supervise construction of the foundation and basement level of the Temple.

The committee members, who had extensive experience with natural stone, masonry, terra-cotta and cast metals for architectural cladding, quickly determined that those materials could not meet the requirements of the Temple's design. They needed a material with the luminous qualities of white marble, the durability of granite, the plasticity of terra-cotta for the complex ornamentation, the strength of cast iron for large spans of thin panels, and an economy that none of the traditional materials offered.

The committee visited John Earley in Washington, DC in March of 1921 to examine Meridian Hill Park, the Potomac Park Field House and exposed aggregate stucco projects that had earned Earley Studio a brilliant reputation within the nascent architectural concrete field. In their progress report the committee concluded that concrete in the form of cut cast stone or applied to the structure's surface would be the most suitable material for cladding the Temple, but further study was required.[32] The Baha'i leadership asked the Materials Committee to continue the investigation.

While construction of the Temple's foundations and basement level took place during 1921, Bourgeois developed his design, preparing eighteen drawings of plans, elevations, sections and details together with sixty-one full size renderings of the Temple's exterior ornamentation. Unrolling huge sheets of paper on the floor of a Chicago loft, Bourgeois would climb a tall step ladder and sketch the elaborate patterns using a pencil tied onto the end of a long stick. His drawings extended as far as 90 ft. (27 m) in length.[33]

The Materials Committee asked Bourgeois to prepare drawings for samples to be made in different cladding materials. Fearful that drawings could not adequately convey his design, Bourgeois had the ornamentation of one window sculpted in plaster. Using casts from this plaster model, 10 in. (250 mm) by 30 in. (750 mm) samples were obtained in John Earley's exposed aggregate concrete, in terra-cotta, and in Algonite Stone, a cast stone of granite chips and white cement that was cut as natural stone. Committee members also inspected Algonite projects in St. Louis, examined the polychrome concrete mosaics that Earley's artisans were completing in the Shrine of the Sacred Heart in Washington, and visited Nashville's Parthenon replica which Earley Studio was constructing.

In their February 27, 1922 report to the Baha'i leadership, the Materials Committee recommended exposed aggregate architectural concrete for the exterior finish on the Temple. They described how the method of application would vary for different conditions on the building, explaining concrete's use as cast stone, applied stucco, cast in place cladding, and precast components spanning a distance of 9 ft. (2.7 m) for the dome. While acknowledging that architectural concretes had not been in use for long, the committee provided justification that architectural concretes provided a durability greater than structural concrete, concluding that "they are as enduring as any other building materials, with the possible exception of granite." The committee stated "while there is not a large amount of competition in the manufacture of this form of concrete, there are probably three or four concerns in the United States who can do it properly. This is about as much competition as can be had in natural stone."[34]

Encouraged by the small samples, the Materials Committee immediately asked Bourgeois to prepare a model for a full-size dome panel 9 ft. (2.7 m) long, 3 ft. (900 mm) wide and 4 in. (100 mm) thick, complete with ornamentation and openings, so that large samples could be procured. The terra-cotta supplier submitted a sample for half of the panel. The Algonite cast stone sample was one third of the panel. Only John Earley was able to produce the entire 9 ft. (2.7 m) long sample[35]. Earley Studio may have created this sample while they were in Chicago building Laredo Taft's mammoth Fountain of Time sculpture. The samples were mounted on timber easels to be exposed to the weather and reviewed over time. Earley Studio's sample remains in excellent condition after ninety years of outdoor exposure on the Temple grounds.

Sitting in the new basement of the Temple, Materials Committee Chairman, Major Henry Burt, remarked to Allen McDaniel that it was "fortunate that [the Baha'is] are unable to proceed with the construction of this temple at this time, because I have a feeling that as the years roll by you will find that the construction of this temple is a matter of growth. It is a matter of growth of our knowledge of construction, our knowledge of materials, which is rapidly developing."[36]

It was now September of 1922. The Baha'is had used all of their construction funds to complete the Temple's basement.

For the next 10 years, while the small Baha'i community of 1,500 members raised funds for the next phase of construction, the investigation into the Temple's cladding material continued. Throughout North America and Europe, the committee examined architectural concrete structures featuring curving surfaces, extensive tracery openings, and varied colors. Committee members visited Notre Dame le Rainey in France, the Church of St. Therese in Montagny, France, the Church of Christ the King in Bischofsheim, Germany, and the Primavera building at the Paris Exhibition of 1925.[37]

CONSTRUCTION PLANS FOR THE TEMPLE

In 1928 Major Burt passed away. The Baha'is contracted with Allen McDaniel and his firm, Research Service, Inc., to provide structural engineering and to supervise the construction of their beloved temple.[38] McDaniel was an accomplished engineer and well-versed in concrete. In 1917, he was awarded the American Concrete Institute's first Wason Medal for Most Meritorious Paper for his manuscript "Influence of Temperature on the Strength of Concrete."[39] John Earley received the Wason Medal in 1923 for his paper on "Building the "Fountain of Time.""[40]

The Baha'is planned to construct the Temple in phases, releasing construction contracts as funds were raised. After carefully analyzing the implications of this phased approach, McDaniel and his team concluded that the most economical course would be to build a complete superstructure enclosed with permanent windows and roofing as the first phase. Subsequent phases would provide the ornamentation of the weathertight superstructure. When the Baha'i leadership asked if this had been done before, McDaniel replied, "Not to our knowledge, but, as Mrs. Trustee wears a gown built upon the dressmaker's form, so, we believe, it will be possible to build the Temple form, and later clothe it with the architect's 'lacy fabric.' "[41] With the radical strategy approved, McDaniel and his team soon completed construction drawings and specifications for the steel frame and reinforced concrete superstructure of the Temple. Bourgeois completed the architectural plans, exterior elevations and details.[42] In the midst of the depression, contractors competed for the project and the superstructure was quickly built in nine months.

One month before construction started on the superstructure, in August of 1930, Louis Bourgeois passed away in his sleep. During the previous 10 years, Earley and Bourgeois had continued to visit and exchange letters, exploring the many artistic aspects of the Temple's ornamentation.[43] Throughout these ten years, the artisans in

Earley Studio were busy creating polychrome concrete mosaics for church interiors and architectural stucco projects with cast stone trim.

The construction drawings prepared by Bourgeois and McDaniels included dimensions and details for architectural cladding variously identified as "stone," "stone tracery" or "art stone."[44] Estimates of the cost to cover the Baha'i Temple in carved stone were ten times the price of Earley Studio's mosaic concrete.[45] Nevertheless, the Baha'i leadership hoped to get competitive bids for the cladding. With drawings in hand, McDaniel traveled the country to meet with industry associations and suppliers of carved limestone, terra-cotta, cast iron, cast aluminum and cast stone, seeking bids to execute the Temple work. In spite of the strong interest that many expressed in the project and McDaniel's repeated appeals, no one would offer a proposal.[46]

When McDaniel knocked on the door of Earley Studio in 1931, John Earley greeted him warmly, "Do come in. I have been expecting you."[47] Earley and his lifelong associate, Basil Taylor, had given a great deal of thought to the Baha'i project.[48] Now, using the construction drawings, they prepared a detailed cost estimate broken into five phases, one for each level of the building. To complete his due diligence, McDaniel spent many hours with Taylor and Earley over the next months investigating and planning every aspect required to carry out the project. They visited quarries of white and crystal clear quartz, developed a shipping and logistics plan, thought through the details of installation and connections to the structure, and translated the schedule into requirements for manpower and production facilities.[49]

Bourgeois' requirements were finally met. McDaniel was satisfied. The Materials Committee was satisfied.[50] The Baha'i leadership entered a cost plus contract with Earley Studio to provide exposed aggregate concrete for the Baha'i House of Worship. As the Baha'is signed Earley Studio's contract in June of 1932,[51] no one realized that the dome of the Baha'i Temple would become a prototype for an entirely new architectural cladding material — exposed aggregate architectural precast concrete panels.

EARLEY AS ARTIST — CREATING ORNAMENTATION FOR THE DOME

The Baha'i Temple beautifully displays John Earley's genius as an architectural sculptor. Without Earley's artistic vision and skill, the Temple's ornamentation may have been mediocre, at best.

As the master architectural sculptor, John Earley actively directed his studio. Visitors regularly found him in his artist's smock when he answered the door. Earley had created an atelier of superb artists and craftsmen, highly coordinated for his production process. John Earley refined a sequence of standard practices for creating architectural concrete. Artisans and craftsmen in Earley's studio worked as a team.

With the passing of Bourgeois, John Earley was solely responsible for developing the architect's ornamentation scheme into its final form.[52] Earley had to resolve the entwining shapes, sculpt the surfaces with vigor and grace, determine the visual balance between solid areas and open perforations, and select a level of modeling detail that the crushed quartz pebbles could adequately render. Bourgeois' numerous sketches and drawings were the most thorough and best executed that Earley had ever seen.[53] The artistic rendering, draftsmanship, scale and proportions in Bourgeois' drawings were impressive, but they were only two-dimensional. Earley decided to immediately move the project into three dimensions.

Earley also decided to move the studio into larger space in Rosslyn, Virginia. The existing studio at 2131 G Street NW, just eight blocks from the White House, was too small for the Baha'i project, although Earley continued to use it until 1936[54] for smaller projects such as the polychrome concrete mosaic ceilings of the Department of Justice Building.[55] Earley's new land was next to the railroad tracks along the Potomac River, across from Theodore Roosevelt Island.[56]

To start the Baha'i project, Basil Taylor built a workshop for production of the models and molds. Taylor then constructed a timber framed, full-size mockup for one-ninth of the Temple dome's structure, carefully duplicating the purlins and furring strips that would support the dome panels. So that sunlight would cast shadows from various angles, the base of the dome section faced east with the dome peak towards the west.[57] Taylor laid out the joints for the dome panels on the wooden mockup.[58] Craftsmen followed the lines of the joints to make wooden templates for each precast panel.

Progress photographs[59] of Earley Studio's work show that half of the plaster models for the dome and ribs were installed on the timber framework before Taylor constructed a 350 ft. (107 m) long crane runway for production of the precast concrete panels. Molds and precast concrete panels were moved along the runway using a rolling bridge with a pair of 10,000 lb. (44 kN) chain fall hoists. Next to the model shop Taylor placed a roof over the crane runway to create an area for processing aggregate and casting panels. Adjacent to the casting area he installed bins to store sand and pebbles, the products of new crushing and screening equipment. The quartz rock was delivered from the quarries in railroad cars, unloaded by hand, stored in an open yard and moved to the crushers in wheelbarrows. Further along the runway he built a 40 ft. (12 m) long curing chamber with wooden walls, pea gravel floor and a canvas roof. At the far end of the runway, Taylor installed a derrick to hoist finished panels into railroad cars on the adjacent track siding.

Earley and McDaniel both credit Basil Taylor as the craftsman who deftly translated the architectural and engineering drawings of lines, angles and dimensions into shapes of plaster and lengths of wood that the studio artisans and craftsmen could readily work with.[60] Taylor controlled the project's geometry by working from the back of the dome panels, the interface between the superstructure and the precast concrete panels. As the control for the models, Taylor had the studio artisans spin a concave, plaster saucer matching the radius of the back of the dome panels. On this saucer the craftsmen laid out the edge of each dome panel, then cast a convex plaster base upon which to model the panel in clay.[61]

The plaster base was set into a vertical orientation on a strong, wooden easel and a 4 in. (100 mm) thick slab of clay was applied. Bourgeois' huge drawings were stretched across the adjacent wall. Leander Wiepert, the studio's master sculptor, transferred the layout of decoration from Bourgeois's full-size drawings to the clay and carved the ornamental relief.[62] A team of artisans then cast an intermediate plaster mold from the clay and, from the intermediate mold, cast a plaster model of the panel. The plaster was reinforced with jute, wood and 2 in. (50 mm) diameter steel pipes.[63]

Lindy, the master model maker, insisted on performing all the work to refine the plaster model, even though he often had to work seven days a week to keep up with the production schedule.[64] Lindy used carving tools to finish the curved surfaces of the plaster model, sharpening its detail and making the lines of the design as true as possible. Plaster models of the dome panels were hoisted into position on the timber mockup so that the ornamentation could be refined across the joints between the panels. The mockup assembly was studied from all angles, inside and outside the dome, and adjustments were made.[65]

When a panel model was approved, craftsmen used it to prepare a watertight mold of many interlocking plaster parts[66] that would be used to cast the intricately sculpted panel in concrete. Fabrication of piece molds is a core skill for sculptors and ornamental plasters. Historical photographs show that every one of the 10,000 openings in the dome panels were created with a plaster plug, uniquely shaped to key into the mold base yet remain within the concrete panel when it was lifted from the mold base. Wire rods were bent into loops and cast into the back of the plaster plugs to help the craftsmen pull the plugs out of the precast panel. Photographs show loose plugs scattered on the base mold while craftsmen are exposing the aggregate surface of the panel. Additional photographs show craftsmen cleaning the plugs and then replacing them in the base mold to prepare for the next day of casting.[67]

Another team of craftsmen applied a thin foil lining to the mold, shaping and attaching the metal skin to tightly conform to the mold's sculpted surfaces. In historical photos, mold parts have a white body with a dark metal foil on surfaces that would contact the concrete. Some photos show a metal foil wrapping up and over the lip of the mold. Allen McDaniel wrote that Earley used an aluminum foil to line the molds[68]. A column mold that Earley used in 1922 for the Nashville Parthenon[69] has a dark, metal foil lining which tested positive for lead. All seams in the foil lining of the molds and plugs were tightly lapped with a smooth finish, consistent with using shellac to adhere the foil to the plaster.

The molds were fabricated to rest upon heavy, horizontal timbers lying on concrete pads in the casting yard. The lower, base portion of the mold remained in place until all required panels were cast. To expose the aggregate on the concrete surface, the panel was lifted from the mold base, rotated into a vertical position and supported against vertical timber posts next to the panel mold.[70]

EARLEY AS CRAFTSMAN — PRODUCING EXPOSED AGGREGATE CONCRETE

The dome for the Baha'i House of Worship presented both an opportunity and a set of new challenges. In John Earley's words, "The character of the work was such that one major technical development was not sufficient to meet all requirements. Many minor improvements and ingenious devices were also needed."[71] In solving the numerous problems, Earley Studio created some of the first architectural precast concrete panels installed on a structural steel framework. The principles and techniques that John Earley and Basil Taylor developed remain sound practices to this day. They provided a gap between the panels for freedom of movement due to thermal expansion and contraction.[72] They used stainless steel connections. They sized the panels for economic efficiency in production, shipping and installation. This was the ultimate separation of the finish from the structure.

Yet, to successfully produce the delicate panels in 1932, Earley found that it was necessary to develop greater initial strength in the concrete than they had previously achieved. He gained the strength by adjusting the size of the sand particles. This gave him improved control of the water during the times of placement and set of the concrete. The Studio also had to overcome severe complications due to the intricate geometry and elaborate sculptural ornamentation of the Baha'i Temple. Yet they reached new heights of artistry and created their most elaborate models and molds, continuing to use plaster because of its ability to be freely shaped when wet.[73]

Before each cast was made, the molds were cleaned and coated with a release agent.[74] Earley Studios' 1933 invoice for the Temple included 100 lb. (440 N) of mutton tallow and 30 gal. (110 l) of lard oil,[75] a good combination for a mold release agent. Mutton tallow mildly retards, or slows down, the hardening of the concrete surface, easing the work of exposing the aggregate. Earley expressed dissatisfaction with chemical retarders as a means to slow the rapid hardening of the cement paste on the surface and claimed not to use them.[76]

During the Temple's restoration, we found that current day cements generated such rapid strength gains that form retarders were necessary to maintain a production schedule of casting on one day with exposure of the aggregate on the following day. We custom blended retarders to adjust their strength for varying conditions in temperature, humidity, mold materials and thickness of the casting. To achieve uniform exposure on complex pieces we applied retarders of different strengths for urethane rubber portions of the mold, vertical surfaces, and flat horizontal areas. At corners where two exposed aggregate surfaces meet, such as between the riser and tread of a step, retarder acting from the two mold surfaces weakens the mortar along the edge, creating a jagged, sawtooth appearance from greater exposure of the pebbles along the edge than in the surfaces. The restoration team maintained sharp, crisp edges by running a plaster fillet of 1/8 in. (3.2 mm) radius along the mold corners after the retarder had been applied. The plaster also made the joints watertight.

The reinforcing rods that Earley Studio embedded into the concrete panels had to be prepared like an intricate sculpture. For structural strength, steel rods 0.242 in. (6.1 mm) in diameter were bent to follow the component's sculpted shape and yet remain exactly 1 in. (25 mm) below the surface. The rods were then spot welded together into a rigid cage and galvanized.[77] After a 3/4 in. (19 mm) thick layer of concrete was placed into every detail of the mold, fixtures made of steel angles curved to fit the radius of the dome were bolted onto the back of the mold to rigidly hold the reinforcing steel and embedded anchors in position for the second phase of the casting process.[78] For sections of walls, pylons and cornices that were cast in place at the Temple site, Earley tied galvanized steel reinforcement onto bolts that were screwed into female anchors previously cast into the structural concrete when the superstructure was built.[79]

The Studio knew that the sparkling quality of the finished appearance depended on the precise size and color of the small stones that would be seen in the concrete surface. To achieve the color and luminosity Bourgeois desired for the Baha'i Temple, Earley selected a blend of white and clear quartz for his concrete.[80] Pure white and crystal clear quartz form in very small deposits.[81] Before the project was completed, three different quarries had to be located and emptied of white quartz.

After moving to Rosslyn in 1933, Earley had railroad cars of rock shipped directly from the quarry to the Studio. They high-graded the material, hand selecting rocks for color and quality, then crushed and screened the stones to the exact sizes they needed. Taylor installed a jaw crusher, a roll crusher, a rotating screen, a two-deck screener and recirculating bucket elevators to produce the pebbles and sand.[82] [83] Before crushing a different color of stone they had to meticulously clean the entire crushing operation – every roller, bin, hopper, screen and lift mechanism part. By recirculating and reprocessing material that was not within the desired sizes, Earley achieved a 70 percent yield.[84] For the restoration of the Baha'i Temple, the Baha'i Concrete Studio used similar equipment and achieved a similar yield.

Earley never described the size of the pebbles used on the Baha'i Temple. The restoration team determined the size by taking samples of concrete from twelve different locations on the Temple and dissolving the samples' cement with acid. The remaining quartz pebbles passed a 1/4 in. (6.3 mm) sieve and were retained on a No. 8 (3.35 mm) sieve. Using similar acid digestion techniques, crushed pebbles of an identical size were found during restoration of the Nashville Parthenon, the Thomas Edison Memorial Tower and the Iwo Jima Memorial.

Although Earley's 1921 patent on gap grading provided an aggregate gradation chart,[85] his sand required an even narrower range of size for successful results. The precise size of the sand was critical to the production, strength and appearance of Earley's exposed aggregate concrete and stucco. Earley's sizes gave the concrete better workability for placement. It prevented segregation and bridging of the pebbles. It provided better flow of the wet concrete. It permitted the craftsmen to fill the most complicated molds.[86] Earley and his licensees maintained their competitive edge by never revealing the size of the crushed sand in their concrete mixtures.

With acid digestion and sieve analysis of samples from the Baha'i Temple, we determined that the original sand passed a 30 sieve and was retained on a 60 sieve. We used sand of this size for restoration work on the Temple.

When writing about the first panels for the Temple dome, Earley reported a major breakthrough in their refinement of the size of the sand. He wrote, "Exactly what we did was to increase the mean diameter of the small aggregate 0.0015 in. (38 µm) by changing the opening of a sieve from 0.0125 in. (320 µm) to 0.0140 in. (350 µm)"[87] A sieve opening of 0.0140 in. (350 µm) is larger than a No. 60 (250 µm) sieve. However, by using Earley's stated dimensions as the "mean" opening of the top and bottom sieves, calculations suggest that Earley used a No. 80 (180 µm) sieve for his smallest screen before the Baha'i project and then switched to a No. 60 (250 µm) sieve in order to extract additional water from the fresh concrete.

After his 1921 patent for gap grading expired, Earley shared his concrete mixture proportions for cement, sand, pebbles and water: 94 lb. (43 kg) or one bag of cement, 110 lb. (50 kg) of sand, 300 lb. (140 kg) of pebbles and enough water for a 0.45 water/cement (w/c) ratio in the final mixture.[88] Earley Studio continued to use these mixture proportions.[89] [90]

Earley's gap graded aggregate made a harsh concrete mixture that was very difficult to place in the mold. Earley overcame this problem by using additional water in the face mix, the first batch of concrete to be placed in the mold.[91] The casting process required multiple batches with varying amounts of water to create different slumps. Water in Earley's first batch varied from a 0.54 w/c ratio with a non-absorptive mold of shallow, open configuration, to a 0.71 w/c ratio for the deep and narrow molds of the Temple's great ribs. After the first one-bag batch was placed, subsequent batches were mixed at a 0.36 w/c ratio.[92] Within two to four hours after placement into the mold, excess water had been removed from the wet concrete by vibration and absorption[93] using burlap,[94] newspapers and fine sand.[95]. The Studio called this their "adjusted slump method."[96]

Earley's original concrete mixture proportions were used for the Temple restoration, but the restoration team decided to maintain a 0.44 w/c ratio in all batches. To achieved satisfactory consolidation we added a high range water reducing agent and a viscosity modifying agent. We also added an air-entrainment agent to the mixture. All the additives for the white restoration concrete had to be especially formulated without tints or dyes so that the repairs would match the brilliant white color of Earley's original white material.

Earley Studio mixed all of the architectural concrete on the Baha'i Temple in small, one-bag mixers[97] and moved the wet concrete to the molds in wheelbarrows. Earley described their consolidation process as a "jolt" such as would be created by a sharp crack with a 3" x 4" timber on the side of a column mold.[98] However, the molds for the Baha'i Temple dome were so massive that a substantial hit with a timber would be unlikely to transfer much force into the fresh concrete. Progress photographs show the craftsmen using small trowels to vigorously hand-tamp the concrete into the fine details of the mold.[99]

For the restoration of the Temple we also used hand-placement and hand-tamping for the initial, 3/4 in. (19 mm) thick, face layer of material. We further consolidated that layer with small, hand-held, plate vibrators. Next, fixtures holding the reinforcing steel and panel anchors were fastened onto the mold and additional concrete was placed to fill the mold. To consolidate the entire volume of concrete in the mold, we employed 1 in. (25 mm) diameter probe vibrators, form vibrators or vibrating tables, whichever was most effective for the shape and size of the mold.

Historical photographs show a large amount of water bleeding from the back of freshly placed concrete. This was consistent with Earley's descriptions. The craftsmen are also seen using thin sticks, similar to paint stirring sticks, to puddle the concrete along the vertical faces of the molds. During the Temple restoration we successfully removed trapped air along the vertical surfaces with the same puddling technique. This reduced the number of "bug holes" in the finished vertical surfaces.

The concrete stiffened enough to be removed from the mold within 18 to 20 hours. As soon as the concrete was in the open air, the surface hardened very quickly. With less than 40 minutes to expose the aggregate on an entire panel, craftsmen worked shoulder to shoulder.[100] The aggregate was exposed with wire brushes shaped like a stubby, 1 in. (25 mm) wide artist's brush.[101]

After exposure of the aggregate, the panels were rinsed with water then hoisted into the curing chamber. On the second day after casting, the exposed aggregate surface was washed with a dilute acid to remove the film of cement haze on the pebbles,[102] rinsed and then cured for fourteen days in a humidity-controlled chamber. The finished concrete received additional air curing[103] and a second dilute acid wash before shipment.

To cast the large, semicircular, precast arches above the Temple doorways, the Studio placed concrete in part of the curved mold, installed a shutter over the fresh concrete, then rotate the mold to place concrete in the adjacent section. This was repeated until the entire arch mold was filled.[104] The restoration used similar techniques to precast soffit and fascia components with complex ornamentation on multiple sides.

Allen McDaniel, John Earley and Basil Taylor collaborated in the design for the anchorage system of the precast concrete panels. They decided to use stainless steel bolts to connect the precast concrete panels to T-shaped furring strips added to the purlins on the Temple's dome structure. When evaluating materials for the furring strips, McDaniel estimated that plain steel had a useful life of 60 to 80 years and stainless steel was too costly, so copper bearing steel was selected.[105] Copper bearing steel is an alloy resistant to corrosion. It has proven to be a good choice, with very little corrosion, even where it is exposed to the weather within the 1/2" wide, open joints between precast concrete panels.

The first components installed on the Temple were the bottom sections of the dome's ribs. The bottom of the rib had to be cast in place on the clerestory level before the rib's precast panels could be anchored into position above. Earley shipped molds and crushed quartz aggregate to the Temple site for the work. The craftsmen installed a metal lathe and cement stucco core mold to define the hollow, interior volume of the massive component, then enclosed the core mold within four to 6 in. (150 mm) of white quartz concrete.

Intricate puzzle-like assemblies have been discovered on the Baha'i House of Worship that combine precast, cast-in-place, and grouted components. Cast-in-place materials were found to lock precast components such as arches into position and to create a seamless finished appearance. Joints at outside corners were made invisible by creating precast pieces with 45-degree beveled edges for one side of the corner. These precast elements were set into molds and cast-in-place quartz concrete completed the other side of the 90-degree corner. Precast modillions had steel loops that extended through openings in precast soffit panels so that the modillions' loops could be "stitched" together with steel rods before the interior of the soffit was filled with cast-in-place concrete. In this way only a few critical measurements were required for installation at the jobsite. The precast pieces and molds nested into each other and wet concrete filled the cavities between the components.

Earley installed two and 1/4 in. (6.3 mm) thick precast panels with intricate ornamental relief as components within larger assemblies. For example, along large areas on the walls of the Temple, thin, precast architrave panels were set with their ornamental face against smooth formwork that extended across the adjacent wall areas. Earley then placed quartz concrete mixtures into the formwork, grouting the void behind the precast panel and filling the adjacent wall area. The formwork was removed the next day and the aggregate in the surface of the flat wall area was exposed to match the precast architrave.

Misaligned surfaces of the Temple superstructure's structural concrete were corrected by Earley Studio in the architectural cladding. During the restoration project an elevator was installed within one of the main floor pylons. We found that Earley Studios had corrected a 3 in. (75 mm) error in the position of the structural concrete by varying the thickness of the cast in place architectural concrete from 1 in. (25 mm) thickness on the west side of the pylon to 7 in. (175 mm) thickness on the east side.

In the final phase of exterior construction, two running miles of monumental stairs were precast on the Temple site using a 1 in. (25 mm) thick face concrete of quartz aggregate and a backup concrete mixture of limestone aggregate. Although this achieved some initial savings in material costs, the stairs required complete replacement sixty years later because of freeze thaw deterioration of the concrete. Even in locations where no deicing salts were used, the stairway treads with the backup mixture failed. Horizontal elements with quartz aggregate concrete throughout the full cross-section, such as large window ledges and pylon capitals, remain in excellent condition. During the Temple restoration project, the monumental stairs were replaced using a quartz aggregate mixture for the entire precast step.

John Earley suffered a massive stroke while inspecting a Washington project in 1945. A few weeks before his death he sold Earley Studio to Basil Taylor for a one dollar.[106] Mr. Taylor directed the work of the Studio as they finished the interior of the Baha'i Temple in 1950. Earley Studio's bid to fabricate and install 2,457 pieces of precast polychrome concrete mosaic panels for the Temple's interior ornamentation was $12,000 less than the bids for ornamental plaster.[107]

CONCLUSION

Earley Studio's innovations were numerous. John Earley pioneered in the use of gap-graded aggregates for aesthetic effect, exposing multi-colored ceramics, glasses and natural stones. Precise control of the aggregates' appearance came through Earley's process of high-grading rock from the quarry, crushing and screening pebbles and sand to exact sizes, and batching in precise mixture proportions.

Production of modern architectural concrete has benefited from Earley Studio's innovations in model making, mold technology, control of water over time, and casting with multiple mixtures. When installing architectural concrete, the Studio often combined precast concrete, cast-in-place concrete and hand-placed cement stucco in entirely new ways. The Studio developed precast concrete shells that were filled after installation, thin precast architectural concrete sections used as molds for cast-in-place structural concrete. They installed precast architectural concrete panels with a stucco base coat, with grout, with anchors to the structure or with cast in place architectural concrete.

The Studio's versatility in production techniques allowed them to take complete advantage of reinforced concrete's characteristics to tackle extreme requirements of form or of color.[108] The precast architectural concrete industry has been built upon Earley Studio's methods of surface finishing, reinforcing, connections, joints, transportation and installation.

Each of John Earley's techniques produced high quality finishes. Each technique offered advantages for different situations. Any one technique could be described as inventive. But in their total effect, John Earley's innovations breathed life and spirit into concrete as a modern architectural material.

John Earley maintained Earley Studio's unmatched quality and economy as a competitive advantage for more than forty years. As his patents expired, Earley licensed other contractors and trained them in his techniques to produce precast architectural concrete of the exposed aggregate type. He provided direction to the Dextone Company for the David W. Taylor ship-model basin in 1936.[109] It was a pivotal project that demonstrated the ability of other craftsmen to apply the refined methods of Earley Studio and create outstanding architectural concrete. Additional contractors followed Dextone's lead and entered the market. Earley's style of architectural concrete was soon available throughout the United States.

Speaking to the American Concrete Institute in 1938, John Earley must have had a smile on his face and a sparkle in his eyes as he explained, "When our craftsmen approached the problem of extending a fairly well developed technique for making plastic mosaics to include the making of architectural concrete and wrapping it around a reinforced concrete structure, they enjoyed a freedom which a scientist can hardly understand or approve."[110] Confident in the value of these accomplishments, John Earley said, "Let the Baha'i Temple be admitted to evidence to support my testimony that concrete of the exposed aggregate type is no longer in an experimental state but is ready for use and is an entirely satisfactory architectural medium . . . there is no masonry material with which as much form and color can be expressed as with exposed aggregate concrete . . . it is now time to make an end of unbelief and doubt in concrete as an architectural material."[111]

Figure 1 — The magnificent dome on the Baha'i House of Worship features the first precast architectural concrete panels anchored to a structural steel frame.

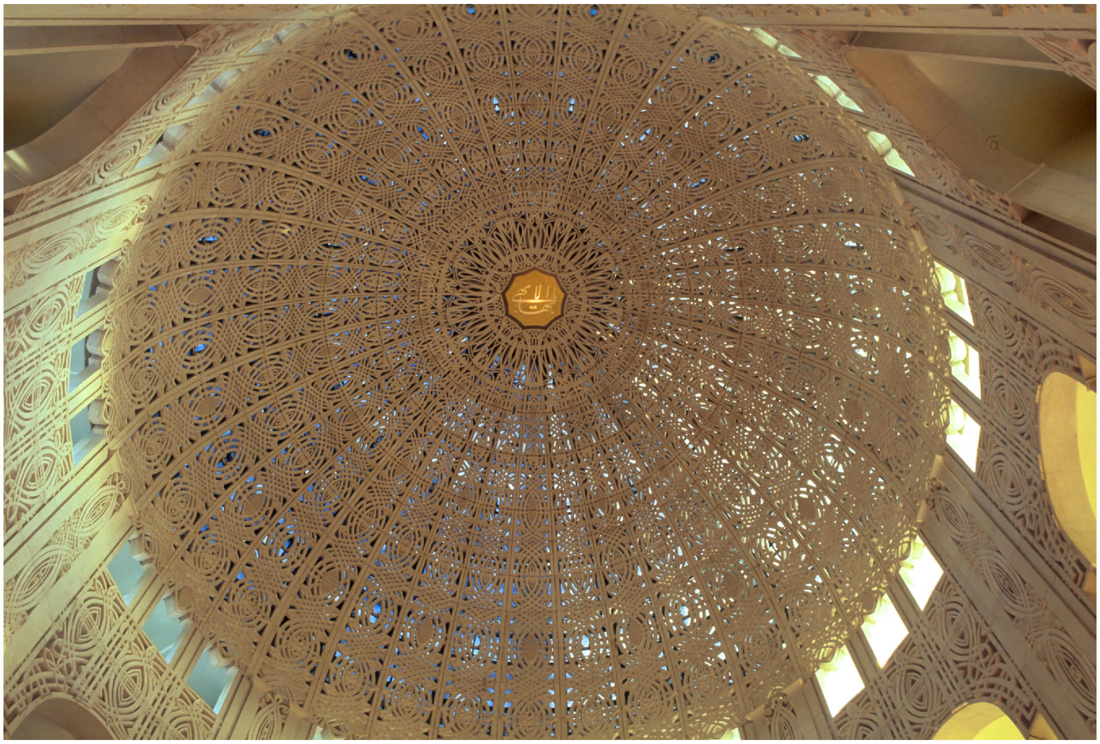

Figure 2 — The precast panels of the interior dome has light streaming in through 10,000 openings in the polychrome mosaic concrete ornamentation.

Figure 3 — The entrances are complex assemblies that John Earley created in exposed aggregate mosaic concrete with precast panels and precast columns. Cast in place ornamentation locks the assembly together.

Figure 4 — In preparation for casting the mold has been coated with a form retarder and plaster is being run in the corners. After concrete is placed in the horizontal portion, shutters will be installed incrementally as the form is slowly rotated for placement of concrete in the vertical portion of the mold.

Figure 5 — The extensive ornamentation on the decorative pylons was cast in place with mosaic concrete.

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