Evaluation and Conservation of Fissures Report

for

Watts Towers State Historic Park

Los Angeles, California

prepared for

State of California

Department of Parks and Recreation

Southern Division Chief's Office

Los Angeles, California

prepared by

Architectural Resources Group

Architects, Planners & Conservators, Inc.

San Francisco, California

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I. EXECUTIVE SUMMARY

In 2004, Architectural Resources Group (ARG) was retained by the California Department of Parks and Recreation (California State Parks) to assess the existing condition and evaluate potential treatments for the fissures found in the upper portions of the three tallest structures and the ornamental floor of the Watts Towers in Los Angeles. In evaluating the conditions at the Watts Towers, Degenkolb Engineers has provided structural engineering assessent, Frank Preusser, has provided input on materials analysis and treatments, and Applied Materials and Engineering (AME) helped in the investigation of the concrete slab at the ornamental floor.

The Watts Towers were built by Simon Rodia between 1921 and 1954. Rodia constructed the towers, walls, and other structures comprising the Watts Towers using salvaged steel of various sizes and shapes for the armature, around which he wrapped wire and wire mesh and then placed cement mortar in lifts ½ inch to 3-1/2 inches thick. The shell of mortar applied to the steel armature and wire mesh was hand formed to create the columns, bands, loops and other elements of the structures that give them their distinctive forms. Embedded in the mortar are colorful fragments of tile, pottery, glass, shell, and other ornament.

From a conservation viewpoint, the Watts Towers can be considered both an artwork in an exterior environment and an architectural composition constructed without following generally accepted standards or conventions. Several major and minor conservation campaigns have been implemented over the years to preserve the Watts Towers. During this time, a refinement in both documentation of repair work as well as the repair treatments themselves has occurred. For example, work undertaken early in the history of the Towers has resulted in the replacement of originally colored cement surfaces with gray cement patches. The current repair approach is to match the existing color and texture of the area being treated. Further, a repair mortar weaker than that of the original is now used so that new repairs will fail before the surrounding historic material. All work is now carefully documented using photography and written descriptions.

It must be noted that a significant portion of the monument has been treated since its original construction; reportedly 40 percent of the cementitious decorative surface areas have been repaired or replaced. This demonstrates the vulnerability of the structure and the constant care required for its preservation. Due to its location in an outdoor environment in which materials will naturally and inevitably degrade, it is impossible to freeze the Towers in time. It must be expected that ongoing maintenance and conservation treatments will be necessary as they are for every outdoor cultural resource. Further and demographic and physical changes to the immediate surroundings of the towers have affected its setting.

Despite the changes to the material composition and surrounding context of the Watts Towers, the structures still retain a great amount of their historic integrity. The authenticity of the other criteria defined in *Secretary of the Interior's Standards for the Treatment of Historic Properties with Guidelines for Preserving, Rehabilitating, Restoring, and Reconstructing Historic Buildings* for evaluating integrity such as location, design, workmanship, feeling, and association is very intact. As much as possible, the local community should be involved with the maintenance and preservation of the Towers to continue the association between the neighborhood and the monument.

The scope of work for the conservation study of the West, Center and East, Towers and the ornamental floor included examination and evaluation of the entire system comprising the structures: the steel armature, the mortar surfaces, and the concrete floor materials. Therefore, in addition to visual examination of the conditions, non-destructive testing of the ornamental floor and mock-ups of potential treatments were undertaken to develop the recommended treatments. Evaluation of conservation maintenance and repair documentation was beyond the scope of this report. However, it is our opinion that the ongoing conservation work is being carried out in an appropriate manner consistent with generally accepted standards of conservation of works of art and architecture.

Although there is some cracking in the mortar shell of the towers, the structures are in good condition overall. This is due in part to the major restoration campaigns at the Watts Towers undertaken beginning in 1979 and 1995 and on to the ongoing maintenance program still underway. Cracks ranging from hairline width less than 2mm wide to larger cracks with associated spalling and edge damage were observed at a total of almost 300 locations on the towers and roughly 100 locations at the ornamental floor. Some of these cracks are in original mortar and others are in areas that have since been repaired. There are three main causes of the cracking observed at the towers and floor: less than ideal environmental conditions or material preparation during mortar application, corrosion expansion of the steel armature caused by water intrusion, and forces exerted by external forces such as wind, thermal stresses, and seismic events.

Without rebuilding the towers or enclosing them to control their environment, it is not possible to completely prevent the type of cracking that now exists at the site. Therefore, the recommended approach to conserving the Watts Towers is to implement a proactive program of routine inspection so that conditions can be treated as part of a comprehensive maintenance program. No matter what technological advances become available to slow processes of deterioration, it is inevitable that this assemblage of dissimilar materials will require repair and maintenance as long as it remains in an outdoor environment. But the continuous care of a historic and artistic site such as Watts Tower should not be seen as an unsolvable problem that will continue to vex those charged with stewardship of this remarkable resource. Rather, a change or shift in the way maintenance is viewed must be made. Instead of being perceived as a nagging difficulty, maintenance of the Towers should be seen as a part of its story and significance. Simon Rodia completed the Towers, but its care and maintenance has been and continues to be a work in progress, a living tradition for all those, near and far, who join in celebrating his achievement and are committed to preserving it. It is especially pertinent to local residents who watch, use and protect the site. The history of involvement by both the Watts community and that of greater Los Angeles with the Towers is made tangible by the daily efforts to preserve it. Clearly, it is the unity of purpose that this care and maintenance represents that should be stressed.

Maintenance is the most conservative preservation approach and also represents continuity of building traditions. This is appropriate for a monument such as the Watts Towers, which was built over many years so that even during its original construction by Rodia much of the work carried out was actually maintenance work. Where cracks are treated during maintenance work, the methods and materials of repair should follow sound conservation practices. In particular, repairs should be completed to preserve as much of the original material as possible. This may mean that at some cracks, injecting grout through existing openings may be preferable to routing out the crack to install a patching mortar. Repairs should also be done using materials that are compatible with the existing materials so that as weathering continues, any deterioration that occurs happens in the replacement materials rather than the original steel and mortar. For example, if steel is replaced at the armature of the towers, the new steel should be painted mild steel rather than stainless steel to reduce the likelihood of galvanic corrosion, and replacement mortars should have a lower compressive strength than the mortar used in the original construction so that the repair will fail rather than the original mortar.

The recommended maintenance program would benefit from further documentation research and material testing that should be undertaken in phase II of the current project. The copious documentation of repairs previously undertaken at the Watts Towers should be reviewed and if possible compiled so that it is easier to use and can be correlated to existing conditions. This would involve consolidating information that is now in a variety of formats into one more easily accessible system. More testing on the effect of chemical treatments such as rust inhibitors and water repellents on the original and repair mortars of the towers should be done before these materials are used in a maintenance program. Part of this testing should include mock-ups done on previously removed material set out for long-term evaluation over one year or more. At the towers themselves, crack monitors should be installed at several locations on each tower and at the floor to establish a baseline for determining the rate of deterioration and crack propagation.

In addition to the synthesis of documentation, inspection and monitoring, and further material testing and mock-ups, several discrete repairs have been identified for Phase II of the project. At the towers, testing to determine the concentration of moisture would help determine whether additional weeps should be installed at the columns and center core to facilitate the evacuation of water from the mortar and steel assembly. The cable restraints should be retensioned and corroding elements replaced. The condition on the north side of the site where open soil lies adjacent to the historic wall and ornamental floor should be addressed to prevent water from traveling underneath the floor, perhaps by constructing a concrete swale or topping to divert water away from the towers.

The types of repairs that should be considered in future work at the towers include grouting and filling of cracks for waterproofing integrity, removal of damaged sections of mortar to treat the reinforcing steel followed by patching, and the localized application of a penetrating rust inhibitor. At the ornamental floor, voids associated with cracks should be stabilized by epoxy injection and large cracks, spalls, and areas of displacement should be repaired with a material that matches the color, composition and texture of the original concrete. As a lower priority, existing incompatible repairs should be replaced when they exhibit deterioration.

II. INTRODUCTION

This report presents ARG's assessment of the current conditions at the Watts Towers, a discussion of appropriate treatments for these conditions, and recommendations for further research, testing, and work to be undertaken as part of the second phase of the project. In considering the existing conditions, an understanding of the original construction and historical context of the towers is necessary. A section of the report with the historical context and construction description of the towers and floor includes this information. The existing conditions are described and the causes of these conditions discussed in the conditions assessment section of the report. The final section of the report, the treatment recommendations, includes a discussion of the range of treatments considered and the appropriate treatment for each condition. In developing these treatment recommendations, on-site, non-destructive testing and a structural evaluation of the towers were undertaken. Items requiring further work and research are also including with the discussion of the treatment recommendations.

The appendices of the report include supporting documentation for the evaluation and treatment of the cracks and fissures at the Watts Towers. Appendix A contains photographs of typical conditions identified during the close-up survey of the three tallest towers and ornamental floor. Photographs of the treatment mock-ups undertaken as part of the evaluation of the conditions and treatments are found in Appendix B. Appendix C is a list of materials tested or proposed for use in treating the conditions identified in the survey and the product data and material safety data sheets for these materials. Appendices D and E are consultants' reports that provide additional structural and materials testing information used in the assessment of the fissures and the development of the treatment recommendations. Appendix F, bound separately, contains documentation of the existing conditions, including an itemized list of conditions and photographs showing the location of each condition.

III. METHODOLOGY

The scope of work for the evaluation of the fissures at the Watts Towers was the assessment of the cracks at the upper portions of the three tallest towers and in the ornamental floor. The fieldwork to evaluate the condition of the towers was performed over several site visits beginning on September 30, 2004. During the examination of the towers and floor, the existing conditions were documented in photographs. Non-destructive testing, such as sounding and ground penetrating radar (GPR), were used to assist in the evaluation of the conditions. Based on the conditions of the towers and current methods for the repair of similar materials and systems, mock-ups of several potential treatments were undertaken. The treatment recommendations discussed later in this report were developed from an analysis of the existing conditions together with an evaluation of the treatment mock-ups. The materials and methods now in use at the towers for repair and conservation work was used as the foundation for the treatment mock-ups and recommendations.

Documentation

At the time of ARG's survey at the beginning of October 2004, complete base documentation suitable for recording conditions was unavailable. Therefore, ARG prepared photographic documentation of the three tallest towers and ornamental floor using a Nikon D70 digital camera. For each tower, photographs showing the north and south sides of each tower in elevation sections approximately 10 to 20 feet high were taken. ARG used the photographs to record the conditions identified during the survey and as the basis for the existing conditions documents found in Appendix F. Conditions observed during the survey of the towers and floor were recorded on prints of the photographs. The digital images were then inserted into AutoCAD and the repairs developed for each of the conditions shown directly on the photograph. Although by no means does the photographic documentation prepared by ARG provide complete documentation of all of the elements and conditions of the towers, it is intended to be sufficient as a way to record the locations of the conditions and repairs for those portions of the towers under study. The photographs are detailed enough to show many surfaces of the tower elements and floor and general enough to provide context for the elements of the towers and floor shown in the images.

ARG also reviewed reports and documentation from previous repair work at the towers and historical research carried out by others on the Watts Towers to gain a better understanding of their construction and materials. These sources are listed in the bibliography of this report. The *Preservation Plan for Simon Rodia's Towers in Watts* prepared by The Ehrenkrantz

Group/Building Conservation Technology in November 1983 and subsequent addenda have been particularly helpful.

Conditions Survey

The survey was primarily visual, with close-range access to all sides of the towers from the arching "overheads" near the bottom of each tower to the very highest point accomplished using a 125-foot boom lift located on the south side of the towers. The portion of each tower below the overheads and the ornamental floor were examined from the ground.

The purpose of the conditions survey carried out by ARG between October 4 and 12, 2004 was to identify cracks and fissures in the mortar shell of the towers and in the concrete slab of the ornamental floor. Each crack was classified as either hairline or a full crack based on its width, and the length of the crack was measured. A clear comparator card calibrated with crack width dimensions was used to estimate the width of the cracks. Other characteristics of each crack in the towers and floor were also noted, such as whether there was edge spalling associated with the crack, whether the crack continued through embedded ornament, and whether there was displacement at the crack.

At the ornamental floor, non-destructive testing was performed to better understand the subsurface condition of the floor. Sounding using a chain and a ball was performed to detect voids and hollow areas below the floor surface. GPR was used in an attempt to locate reinforcing within the structure of the floor.

Treatment Mock-ups

Based on the assessment of the existing conditions and analysis of the component materials, several treatments were considered for the conservation of the cracks and fissures in the towers. Some of these treatments were tested and evaluated on site in early November. Mock-ups of crack repair treatments at areas of extensive deterioration and at fissures through embedded ornament were performed at representative locations. Examples of generalized treatments, such as the application of a water repellent and a surface-applied penetrating rust inhibitor, were also installed as mock-ups for further evaluation.

IV. DESCRIPTION OF THE TOWERS AND FLOOR

Although there is little documentation about the creator of the Watts Towers and the monument that he built from the early period of its construction, as interest in the towers has grown, so too has the body of knowledge about the subject. Although some aspects of the Watts Towers may forever be open to conjecture, such as the inspiration for their construction, there is some consensus on the outline history of the towers and the basic construction methodology. The historical context and description of the towers and ornamental floor presented in this section rely on the findings presented in previous studies by other researchers.[1] Additional information on the original construction materials and methods gained during ARG's fieldwork and research is included where appropriate.

Historical Context

Simon Rodia settled in the southern California town of Watts in the early 1920s, and by 1921 began building the collection of sculptural assemblages and features that are now commonly called the Watts Towers. Over the next 33 years, working alone at nights and on weekends, the tireless Rodia created his magnificent towers, gazebo, fountains, walls, benches, and other structures. He drew on his background in the construction trades, having worked as a laborer, tile setter, and repairman, to build the towers.

Photographs and drawings dated to the period when Rodia worked on the towers show that Rodia built the Center and East Towers first and that construction on the West Tower began sometime after 1938. As he built the Watts Towers, Rodia continued to modify and repair the structures as he felt necessary. For instance, the Center Tower was originally constructed with loops similar to the current configuration of the West Tower. These loops were later removed, perhaps to provide space for the construction of the West Tower, which began in the mid-1930s.

In 1954, Rodia stopped working on the Watts Towers and moved to northern California. Although left in possession of a neighbor in Watts, the towers were, for the most part, unattended and suffered from vandalism and general lack of maintenance for the next five years. In 1959, forced in large part by a 1957 demolition order issued by the City of Los Angeles Department of Building and Safety, the Committee for Simon Rodia's Towers in Watts (CSRTW) was formed and the first preservation efforts to save the towers were undertaken. The CSRTW was successful in arguing for the preservation of the towers, mainly by proving their structural soundness in a test of the lateral load capacity of one of the towers performed in October 1959.

Since 1959, ongoing maintenance work and two major restoration projects have been undertaken at the Watts Towers by the different groups and agencies who have been responsible for their care and upkeep at various times. Between 1959 and 1975, the CSRTW funded projects to fill cracks, repair and replace areas of deterioration at the members, and apply a waterproofing sealer. The City of Los Angeles, granted ownership of the towers in 1975, began a major restoration project in 1978 to repair cracks in the towers. The State of California assumed responsibility for this repair work in 1979, and over the next six years continued the comprehensive effort to stabilize the three tallest towers. In 1985, responsibility for the preservation of the towers was again returned to the City of Los Angeles, under the direction of the Cultural Affairs Department (CAD). Since that time, CAD has directed the continued maintenance and conservation work at the towers, first concentrating on the structures that were not repaired during the 1979 to 1985 restoration project. A second restoration project lasting several years was started in 1994 to repair areas of the towers damaged by the 1994 Northridge earthquake. The current conservation study and proposed repair program should be considered a continuation of the maintenance and upkeep efforts undertaken by many people and groups in an effort to preserve the form, materials, and integrity of the towers since Rodia completed his work.

Towers

Although it is difficult to isolate and separate features and elements of the Watts Towers complex, the focus of this study is on the three tallest towers and the ornamental floor. The description below of the towers is limited to the West, Center, and East Towers that were evaluated as part of this study. In general, the construction methods and materials of these towers are similar.

Each tower is conical in shape and composed of a round base and a number of different structural members, including a center core, vertical columns, horizontal bands, spokes between the center core and columns, and braces between the columns and bands. In addition, each of the towers also contains loops, semi-circular or curved members most obvious on the outside of the exterior columns of the West Tower and at the bottom of the Center Tower, and also present

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[1] Much of the historical context and description of the towers and ornamental floor presented in this section is drawn from information presented in *Preservation Plan for Simon Rodia's Towers in Watts* prepared by The Ehrenkrantz Group/Building Conservation Technology in November 1983.

at the interior spaces of the East Tower. Overhead arches connect the towers to Rodia's concrete site walls approximately 10 feet above the ground.

Two small sets of steps at the West Tower lead to a circular base that consists of four stepped levels beginning 4 feet above the floor and ending 8 feet high. The tower measures 15 feet at the base and rises to a height of 99 feet-6 inches. The West Tower has 16 exterior columns at the outer perimeter of the tower. A distinguishing feature of the West Tower is the series of vertical loops outside of the exterior columns. There are a total of 18 loops, climbing from nearly the bottom of the tower to the top every two to three exterior bands. (See Appendix A, Figure 1)

The Center Tower, situated between the West and East Towers, has a dome-shaped base 8 feet high at the center core. The Center Tower is 13 feet-6 inches in diameter at the base and is 96 feet-10 inches high. There are eight exterior columns at the perimeter of the base, and another eight intermediate columns between the center core and the outer columns. There is a ladder-like series of sub bands, most numerous on the north side of the tower, in between the regularly spaced exterior bands completely encircling the tower. A single level of vertical loops near the bottom of the tower, approximately 20 feet from the ground, is the remaining vestige of loops that originally climbed the full height of the tower, similar to the West Tower, but were removed by Rodia before the construction of the West Tower. (See Appendix A, Figures 2 and 3).

The East Tower, 9 feet in diameter at the base and 57 feet high, lies east of the Center Tower and is connected to it by a series of overhead arches. The base of the East Tower is 3 feet high and made up of a series of circular levels of decreasing diameter. The tower has six exterior columns and eight interior columns. (See Appendix A, Figures 2 and 3).

In general, the towers are composed of a metal armature to which wire mesh was attached and a cementitious mortar was applied. Ornament was then embedded in the mortar. Steel angles, rods, pipes, and railroad ties were used as the metal armature for the vertical elements, and smaller bars, channels, or rods used in the horizontal bands and loops. The metal pieces of the armature were spliced together at joints and the intersections of the vertical and horizontal members by overlapping the metal and wrapping connection with steel or copper wire. Wire mesh and metal lath wrapped around the metal armature was typically used to provide additional strength and to improve the application and adhesion of the mortar shell.

The mortar applied to the metal armature and wire mesh by Simon Rodia varies in color and texture, but the most commonly used material is a gray cement-based mortar with coarse aggregate. Previous analysis and testing of the original mortars concludes that the ratio of aggregate to cement in the mortar mixes were consistently between 2-1/4 and 3 parts aggregate to 1 part cement. No lime was identified in the mortar analysis, but it is possible that Rodia may have added lime to improve the workability of the mortar. Some of the mortars used on the towers are pigmented red, green, yellow, or blue, and in some cases a colored wash or stain was applied. (See Appendix A, Figure 14). The depth of mortar cover over the wire mesh and metal armature varies between 1/4-inch and 1 1/2-inches, and is typically 1/2-inch thick. Previous repairs to the towers have included the installation of cable braces between the center core and exterior columns of the Center and East Towers and the addition of weep holes at the center core and bottoms of the exterior columns. (See Appendix A, Figures 15 and 16).

Set into the mortared surfaces of the towers are thousands of ornamental elements. These embedments include broken and whole pieces of tile, pottery, glass, shells, and other decorative items. The visual effect of the embedments implies that Rodia carefully selected and placed the embedments with deliberate organization.

Ornamental Floor

Within the concrete walls that define the site of the towers, Rodia constructed an ornamental floor consisting of colored concrete with stamped patterns. (See Appendix A, Figure 18). The floor, mostly green concrete with some fields of red and yellow, was poured or set as a slab of varying thickness at various stages throughout the construction of the towers. The slab is scored, although not in a regular pattern, as is typical in concrete flatwork, and has relatively large spans between score lines. The top surface of the slab was stamped with heating registers, rug beaters, and other household items to give it a distinctive visual appearance. The joints or score lines between the colored slabs appear to be a function of the artistic design rather than placed specifically for crack control.

Several tests were performed on the ornamental concrete floor in October 2004 by AME. All tests were non-destructive. The first test was a survey of the slab to detect reinforcement using a Fisher M-100 reinforcing locator. The locator is capable of locating ½ inch diameter reinforcing bar at a depth of approximately 3-½ inches. GPR was also used to detect reinforcing within the slab. Both methods of testing did not detect the presence of any reinforcing steel. Based on the data, AME determined that there is probably no reinforcing steel within the slab, and that the individual slab sections are not tied to one another with dowels.

A "chain drag" survey was conducted over the entire surface of the slab to detect delaminated surfaces and unsupported slab conditions. The test was conducted in general accordance with ASTM D4580, "Detecting Declinations in Concrete Decks by Sounding." Isolated areas of the deck produced hollow sounds, indicating areas of delamination and/or unsupported slab. Most of the areas of delamination are small, with the exception of a large area west of the central tower and the concrete flooring in the gazebo.

Another test was performed to determine the uniformity and quality of the concrete and to estimate the in-place compressive strength. The testing followed the procedures outlined in ASTM C805, "Standard Test Method for Rebound Number of Hardened Concrete." In this test a spring-driven steel hammer (Schmidt hammer) is placed on the surface of the concrete and the rebound numbers recorded. Testing was limited to four discreet locations in an effort to minimize the number of small dimple marks that the hammer produced on the concrete. The average rebound number was 42, and was similar at all four locations. The number 42 indicates a relatively strong concrete, based on the calibration scale for the Schmidt hammer.

A soil sample was removed from the north side of the slab (directly north of the central tower) for laboratory testing. The purpose of the testing was to determine if the soil was expansive and could have contributed to the cracking in the concrete floor. The soil was tested in accordance with ASTM D4318 "Standard Test Method for Liquid Limit, Plastic Limit and Plasticity Index of Soils." The test results indicate that the soil is composed mainly of dark brown silty sand. Sand is nonplastic, therefore the soil is considered to be nonexpansive. The moisture content of the sand at the time of sampling was 5.5%

Based on the testing, AME concluded that the ornamental concrete floor does not have any reinforcement and that the sections are not tied together with dowels. They also determined that areas of delamination and/or unsupported slab were common. The soil test indicated that the soil was nonexpansive, so it probably did not contribute to the cracking in the slab. The full report prepared by AME is included in Appendix E.

V. CONDITIONS ASSESSMENT

Over six days in early October 2004, ARG examined the three tallest towers from a 125-foot boom lift and the ornamental floor from the ground, recording the location and size of each crack and fissure in the mortar shell of the towers and concrete slab of the floor. ARG also noted conditions relating to cracks in the mortar and concrete, such as corrosion at reinforcing and wire mesh. In evaluating the conditions observed, it is necessary to understand the entire system of materials, comprised of the metal armature or reinforcing, wire mesh or lath, and mortar or concrete. There is some degree of inherent vice present in composite materials such as concrete and mortar. The mineralogy of the aggregate present in the mixture may be a factor in the performance of the material. In addition, with the introduction of steel and other metals used for reinforcing and pottery, glass, shell and other embedments on the surface of the mortar, there is more interaction between materials with different physical properties that can eventually lead to failure.

In the following description of the conditions at the towers and floor, each type of condition is presented along with a discussion of the relationship between these materials. As much as possible, ARG attempted to make a determination of whether the conditions observed were in original material or repair material added after 1954. However, it proved to be difficult to tell whether some areas of the towers had been previously repaired or not based solely on visual examination.

Towers

Cracks ranging in size from hairline to widths large enough to see reinforcing material occur in each of the three tallest towers and at all heights of the towers. There is not a clear pattern to the cracking, although in the case of the Center Tower, vertical cracks over several levels at the exterior columns appear to be related to each other and most likely caused by corrosion of the reinforcing. Although it is not always possible to identify areas of previous repair based on the visual characteristics of the mortar, it is clear that the cracks observed in the towers occur in both original mortar and in areas that have been previously repaired. Examining the cracks without reviewing documentation of previous repairs, it is nearly impossible to determine the rate of cracking and whether there is a progression from hairline cracks to larger cracks.

There are several causes of the cracking in the mortar shell of the towers that can act alone or in combination. Fissures may result from external forces, such as thermal stresses, wind loads, and seismic events that cause the thin mortar shell to crack. Once a crack has formed, it functions as a path of entry for water into the structure, compounding the problem by leading to corrosion of the internal armature. Many of the conditions observed at the towers are related to the ingress of water that then causes metal corrosion. The iron-based corrosion products of steel expand as they form, exerting forces on the surrounding mortar that can lead to more cracking. Some of the cracking noted in the repair mortar may be due to unfavorable weather conditions during application or incomplete preparation for the repairs that subsequently causes cracking. There are so many variables that affect the integrity of cementitous repairs, such as water content of the mortar or concrete, climate during application, and timing of the curing process that without careful attention to all of these factors, there is a significant potential for cracking and failure.

Cable restraints spanning between the center core and the exterior columns at the Center and East Towes were installed to control movement in the towers. The cable braces appear to be functioning as intended to provide additional lateral connections between the center core and the columns and do not appear to be causing further damage to the towers. However, since installation five years ago, the clamps have begun to rust. In addition, the turnbuckles at the restraints are of an open-ended type inappropriate for the application.

Condition type 1: One of the common conditions noted in the survey of the towers are hairline cracks. (See Appendix A, Figure 4). The use of the term 'hairline' in describing cracks in concrete or mortar is generally agreed upon to refer to cracks so small in width that they are barely perceptible and are nonstructural.[2] Another criterion used in the Watts Towers survey was that cracks having a width less than 0.5 millimeters, or 0.02 inches, were classified as hairline cracks. Approximately 70 hairline cracks were noted in the three tallest towers. The majority of the hairline cracks identified in the survey are in areas of previous repairs. This includes a few areas where there are multiple hairline cracks in a pattern of craze cracking. (See Appendix A, Figure 5). Hairline cracks can be caused by a number of factors, including shrinkage of the mortar during its initial set, differential expansion of materials due to corrosion of reinforcement, movement, or wind, seismic, or thermal stresses. Crazing of cementitious materials usually occurs because proper application procedures were not followed, resulting in high evaporation during initial cure or too wet a mix, although it can also be caused by carbonation of the surface layer which results in shrinkage of the cementitious material. Even at hairline cracks, moisture,

[2] ACI Committee 201, "ACI Report 201.1R-92: Guide for Making a Condition Survey of Concrete in Service," (American Concrete Institute, 1992).

which generally refers to dampness caused by either liquid water or water vapor, can penetrate the mortar and lead to further metal corrosion and mortar cracking.

Condition type 2: There are over 100 cracks at the three tallest towers that are larger than hairline width and where the mortar at the edges and around the crack is sound. (See Appendix A, Figures 6 to 10). These cracks vary in length from 1 to 2 inches to over 48 inches. The longer, wider cracks tend to occur on the exterior columns. The most likely cause of these cracks is differential expansion of materials due to corrosion of the internal reinforcement that has caused the displacement of the mortar shell. Once the crack is larger than hairline width, water can more easily enter the crack and the metal corrosion-mortar cracking cycle propagates. Although there is no obvious pattern to most of the cracking observed at the towers, the exterior columns on the Center Tower exhibit a series of vertical cracking that is most likely due to corrosion of the armature.

Condition type 3: Some of the cracks through the mortar shell also run through embedments. (See Appendix A, Figures 11 and 12). There are 16 examples of this condition on the three towers. This does not include the cracks that travel through areas where there is an impression of a former embedment or where there was once an embedment that is no longer present. The cracks through the embedments affect all of the different embedment materials. The presence of glass, ceramic, shell, and metal embedments introduce another cause of cracking because the embedments may concentrate thermal stresses or result in differential coefficients of thermal expansion and contraction.

Condition type 4: In some locations, edge damage or spalling is present at the edges of cracks through the mortar. This additional type of deterioration may result from dissimilar movement of the materials through which the crack travels. One of the causes of the edge damage may be incompatibility of materials.

Condition type 5: In some cases, there is iron staining associated with the cracking, typically at the bottom of the crack. (See Appendix A, Figure 11). This indicates that there is active corrosion at the steel armature or wire mesh, and the corrosion products are being carried to the mortar surface by water and moisture. There are also areas of exposed wire mesh, where the shallow cover of the mortar shell has eroded or was insufficient in its original application to completely cover the mesh. (See Appendix A, Figure 13). In most cases, corrosion of the metal is visible, but there is no cracking, spalling, or other deterioration at the surrounding mortar. Most of these areas of exposed metal are quite small, typically less than 6 inches by 6 inches.

A full survey of the condition of the ornamental embedments on the towers was beyond the scope of this project. However, ARG briefly examined most of the embedments to gain a better understanding of the integrity of the entire material system. Most of the embedments are firmly adhered to the mortar shell of the towers, either because they retain their original bond to the mortar or because they have been reattached during previous repair work. In one case, a loose embedment, a piece of plate glass near the top of the Center Tower, was identified. The location of the embedment was recorded and photographed, and the embedment was removed for safety and given to the on-site conservator for reattachment at a later date. ARG also noted many instances of missing pieces of embedment and recorded some, but not all, of the locations of such conditions on the photographs used for the survey.

Ornamental Floor

There are a number of conditions of deterioration at the ornamental concrete floor. These conditions include cracks of various sizes, voids between layers of the floor slab, spalling of the original concrete material, minor displacement, and repairs to the concrete surface that do not match the original material in composition and color. Like the towers, cracks range in size from hairline cracks, with an approximate spacing of 1" to 2" between the cracks, to cracks up to 1/2" in width. Most of the cracks appear to be older, with dirt in the cracks or previous repairs. No corrosion products were noted at the cracks, indicating that they are caused more by movement than corrosion of any internal reinforcing.

One of the patterns observed in the cracking of the ornamental floor is a series of cracks connected by score lines in the floor that encircles the Center Tower. There is no displacement at this crack, indicating that it is not related to an active structural condition and the more likely cause may be related to the foundation material underneath the center tower. In general, drainage of water off of the ornamental floor is good. Water that falls on the floor tends to drain toward openings at the bottom of the north and south walls. These openings, roughly 4 inches by 4 inches, are assumed to be original to Simon Rodia's construction and intended for this purpose. One location that does not drain well was observed on the north side of the Center Tower. At this location, two sections of concrete slope downward toward each other, forming a valley where water collects. This condition may be original to the construction of the floor, as there are no signs of cracking or later displacement that would indicate a later condition. There is also poor drainage of the ornamental floor at the northwest corner of the site, where water can penetrate below the floor slab at areas of open soil. At this location poor drainage and movement of the soil underlying the ornamental floor has resulted in severe displacement of the floor.

Condition type 6: There is a considerable number of random hairline cracks at many locations of the flooring. The ornamental floor consists of large expanses of colored concrete with relatively wide spaced joint lines. Although the stamped patterns of the floor may act like score lines to some extent, the hairline cracks may be shrinkage cracks which occurred during the initial curing of the concrete because there were not sufficient score lines to relief the stresses of the curing concrete.

Condition type 7: One of the conditions detected by non-destructive testing performed at the floor is the presence of voids between the two layers of concrete forming the ornamental floor or between the lower slab and the underlying soil. There are often cracks associated with these voids. The largest continuous void is located at the west end of the site between the wood platform representing Rodia's house and the gazebo structure. This void and the severe displacement of the floor near the northwest corner of the site are most likely related to water penetrating below the floor slab at the exposed soil to the north side of the site, just outside the historic concrete wall of the site, resulting in erosion or movement of the soil and slab above it. The voids do not present a danger of collapse and complete failure of the floor, but they do contribute to the cracking and displacement that was noted in several locations.

Condition type 8: Cracks that are larger than hairline are each documented on a photograph. These large cracks may also have some edge damage along the length of crack, or exhibit some minor displacement. The cracks that exhibit minor displacement were noted because they could potentially be a tripping hazard. There is one location where more distinct displacement occurs, this area is in the northwest corner of the site adjacent to the gazebo. (See Appendix A, Figures 19 to 21). There are a number of spalls on the concrete flooring; however, most are small and exist in locations that are vulnerable to spalling, like the areas where the metal gates attach to the concrete flooring. (See Appendix A, Figure 22)

Condition type 9: Perhaps the most noticeable deficiency on the concrete flooring is the areas that have received repairs, some of which may be quite old and even date to Rodia's work. (See Appendix A, Figure 23). The color of the mortar used to repair the cracks often does not closely match the color of the original concrete. It is difficult to match repairs to colored concrete and results are not known until the patch has cured. Sometimes the aggregate used in the repair mortar differs from the original concrete. This makes the repair stand out more because the texture on the surface is different. Many of the crack repairs span over an area of the concrete with an original stamp or pattern. Often times, the pattern was not recreated in the repair or the repair covers a patterned area, which also tends to make the repair more noticeable. The repaired cracks all appear to be watertight, so the deficiency is actually more one of aesthetics.

VI. TREATMENT RECOMMENDATIONS

In developing treatment options for the towers and ornamental floor, a range of treatments from deferring all repairs to recreating larger sections of the towers was considered. Although there is cracking in the mortar shell of the towers and at the ornamental floor and there are obvious signs of continued corrosion, there did not appear to be any areas that are potential falling hazards, but every indication is that the cracks are progressive. The mortar around the areas of cracking is generally sound and no loose material was in imminent danger of falling, with the exception of the glass embedment removed from the Center Tower mentioned previously. However, the cracks and other conditions present a waterproofing concern. By allowing water to enter the structure where it can lead to further corrosion of the metal armature, the cracks are contributing to the ongoing deterioration of the towers. Treatment of the cracks, therefore, is necessary to stabilize the structure. The basic nature of the conditions suggests that the repairs should be relatively light-handed, preserving as much of the existing material as possible without rebuilding large areas. Overall, the recommended approach is to preserve the towers in their current condition, continue research of the previous repairs and proposed treatments, and to provide protection from further deterioration of materials at discrete priority areas.

Given the overall condition of the towers and ornamental floor, one minimal treatment option considered by ARG for the immediate future is to defer treatment of the cracks and other conditions for one or more years, using available resources to instead prepare documentation that can be used to assess the performance of previous and proposed repair materials and monitor the rate of deterioration. Such documentation would include detailed three-dimensional digital models of the towers showing all the existing conditions, as well as instrumental devices for measuring crack movement. If the cracks are not treated in the coming year, another comprehensive inspection of the towers would be necessary in two or three years to examine the conditions and collect data for assessing the deterioration. Another treatment approach is to consider all areas of the mortar shell containing cracks as being potentially unsound and to replace these sections of the towers and floor. The argument for this reasoning is that many of the cracks are caused by expansion of the internal metal as it corrodes. The surest way to treat the cause of the problem is to remove enough material to treat or replace the steel armature. This would lead to removal and replacement of a large amount of material. Some of these repairs would be at previous areas of repair, but some would involve removing original material, beyond the nearly 50% of mortar that is already replacement.

Treatment Mock-ups

Over two days in early November 2004, mock-ups of crack repair treatments were performed by ARG. Photographs of these mock-ups are included in Appendix B. At two previously repaired cracks at vertical columns, mock-ups were performed to assess different repair materials at vertical cracks. Mock-up number 1 was at a crack on the south side of an intermediate column at the East Tower, and mock-up location number 2 was on the north side of an exterior column at the Center Tower. Each crack was cut out using a variable speed rotary tool with diamond carbide bits, a grinder, and hand tools, and three treatments were installed in different sections of the crack. At roughly 1/3 of each crack, an epoxy resin, Sikadur 23, was installed. A urethane sealant, Sikaflex 15LM, was installed at another 1/3 portion. Jahn M90 repair mortar was then installed over the remaining portion of the cracks and on top of the epoxy and urethane materials. Oxide pigments were added to the Jahn mortar to match the color of the surrounding mortar. (See Appendix B, Figures 1 to 8).

At the horizontal surfaces of the East Tower base levels, crack repairs were performed to develop color mixes for matching the green (mock-up number 3) and red mortar (mock-up number 4) of the towers. At each of these repair mock-ups, epoxy grout had previously been injected at the cracks. The cracks were routed out and Sikadur 23 was installed the length of the crack recessed about 1/4 inch. The crack was then filled with a color-matched Jahn M90 repair mortar and covered with wet cloth to cure. (See Appendix B, Figures 9 to 13).

Mock-up number 5 was performed at a crack through a tile embedment on the center core of the East Tower. The crack through the mortar was routed out and patched using Jahn M90 repair mortar. The crack through the aquamarine tile was filled with a pigmented mix of Thin-Fill 55, which was worked into the crack using a razor blade and a sponge. (See Appendix B, Figures 14 to 16).

In addition to these completed mock-ups, a portion of the original Simon Rodia mortar on the interior face of a band on the West Tower was removed to reveal the steel armature. A large crack at the bottom of the band indicated that there was active corrosion and deterioration. The steel was in poor condition and required additional assessment by a structural engineer. (See Appendix B, Figures 17 and 18). At another location on the West Tower, the mortar edge along a crack at one of the horizontal levels at the base of the tower was removed. Approximately 24 inches of the mortar edge was removed in four sections. The mortar pieces were cleaned for reinstallation using an epoxy adhesive, SikaFix 2. (See Appendix B, Figure 19)

Recommended Actions

Synthesis of Documentation

Because the history of the towers and their repairs is as important to developing an understanding of the conditions as the physical material is, additional work is recommended to review, consolidate, and synthesize the documentation of the towers. Future work at the Watts Towers should be based on understanding the complete history of the towers and should build on what has previously been done. By thoroughly reviewing the previous documentation, it may be possible to determine how many of the existing conditions occur at areas that have previously been repaired and what the chronology of interventions has been. This information can be linked to a three-dimensional model of the towers so that the treatment history and existing condition of each area of the site is easily retrievable and viewable.

There is a large amount of existing documentation on the condition and repair history of the Watts Towers. This documentation is in several formats, including written reports and treatment records, spreadsheets, color transparencies, digital images, and microfiche. ARG recommends consolidating this documentation to create a single, easily accessible source of information. For instance, the color transparencies can be digitized and integrated with the existing digital images spreadsheet in a program, such as Microsoft Access, to create a database of conditions and repairs that incorporates both raw data and graphic images. The AutoCAD drawings created by ARG to document the location of existing conditions can be linked to this database so that the repair information that appears in the spreadsheet is the same as the information that is included in the drawing file and vice versa. Alternately, the drawing files can be imported into the Access database as graphic files. The documentation information could also be synthesized on the model of GIS programs that link location information with data input. Although it would take a fair amount of time and considerable patience to consolidate the documentation, the information contained in the database would be easier to use and more accessible in the end.

Another tool for documenting the towers is to create a three-dimensional electronic model of the towers using laser scanning technology. Such a model could be used for quantifying structural assessments that tend to be qualitative and empirical without the raw data that the model would provide. For instance, after examining the repair records to identify the exact structural composition of the towers, the model could be used as an analysis model to simulate various events and outcomes. A three-dimensional model with data on the existing dimensions, fissures, and other conditions could also be used as a baseline to evaluate future deterioration of the mortar and the embedded ornament.

During the upcoming repair program, ARG recommends taking large-format color transparency photographs of the three tallest towers and ornamental floor following the same parameters that were used by Marvin Rand in the early 1990s. Each section of the towers and the floor would be photographed in 4-foot by 4-foot sections. This would provide a useful tool for comparing the conditions that existed in the 1990s with the existing conditions. The scaffolding necessary to perform the large format photography would be in place as part of the upcoming repair program.

Monitoring and Inspections

One of the goals of a thorough review and synthesis of the existing documentation is to determine whether the existing conditions are due to problems inherent to the original construction of the towers and floor, to problems that have been introduced by later interventions, such as the use of inappropriate repair materials and changes to the land adjacent to the site, or some combination of the two. Regular inspection and monitoring of the conditions is also necessary to answer these questions.

As part of the next phase of work, crack gauges such as Avongard's crack monitor should be installed to measure movement that may occur across existing cracks and help quantify the rate of deterioration. The gauges consist of two overlapping acrylic plates, each of which is attached to the concrete structure using epoxy or another adhesive. Three to six crack gauges should be installed on each tower at representative hairline and wider cracks near the bottom, middle, and top of each tower. Alternately, electronic crack gauges can be installed which would record data remotely so that the information can be accessed at any time without examining the cracks themselves. The disadvantages of the electronic monitoring system, provided by OSMOS, is its expense and the use of cables running between the gauges and the ground.

Even if remote crack gauges are used, the towers and floor should be inspected periodically for visual examination of the conditions and assessment of their change. It is recommended that the first inspection take place two to three years from now. Subsequent inspections should be performed every three to five years, depending on the findings of the first inspection. These inspections can be done from a 125-foot or higher boom lift using existing documentation as a guide to the critical areas for examination. The data collected from the crack gauges to be installed at each of the three tallest towers should be analyzed as part of the inspections.

Material Testing and Mock-ups

In order to better understand the long-term effects of some of the materials considered for use at the Watts Towers, additional material testing and mock-up installation is recommended.

Mock-ups for long-term evaluation performed on pieces of mortar and steel previously removed from the towers or on replicated mortar materials should be prepared as part of Phase II. The application of a water repellent to mortar surfaces as a protective treatment to help prevent the infiltration of moisture, as well as chloride ions to the metal armature was considered in the assessment of repair materials. Clear water repellents provide a barrier against liquid water infiltration and reduce deterioration due to atmospheric pollution and biological growth. Tests are currently underway both on a small area of the East Tower and a sample of previously removed mortar and reinforcing to assess the performance of Sikagard 701W, a penetrating silane-modified siloxane. (See Appendix B, Figures 20 to 23). Siloxane water repellents typically have good penetration and dry relatively quickly. Sikagard 701W also has the advantage of being solvent-free, it does not alter the optical properties of the mortar and embedments, and it does not change chemically. It also reduces dirt penetration and will not form a vapor barrier. The mock-up of the water repellent treatment should be evaluated to determine if the different mortar materials are affected differently by the repellent and how the path of moisture at cracks is affected by the water repellent.

Another treatment that should be evaluated as part of a mock-up is staining or applying a colored wash or mineral paint coating to the tower members that were entirely rebuilt using gray mortar, particularly at the bottom of the three tallest towers, to replicate the original colors of these members. There is physical evidence at some of these elements, especially some of the exterior columns, that they were originally yellow, red, or green mortar. Reviewing the repair database and photographs would provide additional information that could be used to determine the original colors.

Discrete Phase II Repairs

Although more research and testing is necessary before finalizing the treatment materials and methods for the repair of cracks, spalls, and voids at the towers and floors, several discrete repairs have been identified that can be performed as part of the second phase of the current project. These repairs can be done independently of the current maintenance work at the towers and do not preclude future research or treatment at the conditions discussed above. The discrete repairs recommended for Phase II include the drilling of weep holes at several locations on the towers, the repair of the cable restraints at the center core of the towers, and the installation of a concrete swale adjacent to the site to improve drainage from the ornamental floor.

One of the accepted concepts of concrete and masonry construction is to allow water that enters a structure to weep out through holes. At the Watts Towers, several holes that appear to be acting as weeps already exist at the exterior columns near the bottom of the structure and at the center columns of the towers. These holes should be tested to make sure they are clear. Because there are so many levels of each of the towers that may not have continuous connections and voids for water to travel along, it is recommended that additional weeps be installed at discrete locations of the columns and center core, especially at elements that have pipes and tubes used in the armature that may hold water. It may be possible to determine the best location of the weeps by performing thermography testing, which would locate the areas of higher moisture concentration. The weeps should be no bigger than 3/8 inch in diameter and drilled upward into the tower element to facilitate the evacuation of moisture and to discourage material from clogging the weep. A nonrepercussive drilling tool should be used to avoid further cracking and spalling of the mortar.

The cable braces at the Center and East Tower are functioning as intended to provide additional lateral connections between the center core and the exterior columns and do not appear to be causing further damage to the towers. However, since installation five years ago, the clamps have begun to rust. In addition, the turnbuckles at the restraints are of an open-ended type inappropriate for the application. The clamps should be replaced with galvanized clamps and the turnbuckles replaced with a type that has a closed welded end. When these minor modifications are made, the cables should be retensioned.

The displacement of the ornamental floor at the northwest corner of the site appears to be directly related to the condition of the ground on the opposite side of the historic concrete wall. At this location, a swath of open soil runs along the north wall adjacent to the ornamental floor. Water absorbed by the soil can easily find its way beneath the concrete slab of the floor, displacing it as the soil expands and contracts. To remediate this problem, a concrete swale should be constructed along the north side of the wall to reduce the amount of water absorbed by the soil and to improve drainage away from the site.

On-going Maintenance Program

The most important element in the conservation of the Watts Towers is a comprehensive maintenance program that includes inspection, monitoring, and judicious treatment of the conditions at the towers and floor.

Cracks in the towers and floor should be inspected periodically to evaluate the rate of deterioration. If deterioration progresses, treatments should be based on the use of compatible materials that will preserve the original material as much as possible. The types of repairs appropriate for use at the towers are discussed below. Overall, the drainage from the concrete surfaces at the ornamental floor is good, with the exception of the valley north of the Center Tower where water collects during rain. Rather than altering the original construction at this location and rebuilding a large section of the ornamental floor, a site maintenance approach is recommended to address this problem. Following rain or other periods when water might collect in this area, the water should be removed using a mop, squeegee, or large sponges.

The maintenance program at Watts Towers should promote the input and participation of the local community. The Watts neighborhood that gave birth to the towers through the vision and work of Simon Rodia has changed significantly since Rodia completed his creation but the towers still remain a monument for the local community. Maintenance represents continuity, and continuing the strong connection to the local community is the most effective way to preserve the living tradition of Watts Towers.

Guidelines for visitor access should be clearly defined and enforced as part of the maintenance program to minimize the threat of vandalism to the towers. The fundamental reason for preserving the Watts Towers is to allow the public to view a truly unique work of art and architecture and contemplate the creative process of Simon Rodia. The recommended program of crack repairs and protective treatments to be undertaken by the State of California and the City of Los Angeles will help to ensure that the towers remain accessible and visible for many years to come. Responsibility also falls on the public, through the encouragement and enforcement of the towers' caretakers, to minimize the potential for damage to the site and structures. Food and drinks, including water, should continued to be prohibited from the enclosed portion of the site. In addition, the public should not be permitted to touch, stand on, or climb the structures, including the steps and low walls of some of the structures. It is important that the towers remain open to the public, but it is also important that the public show the care necessary for their preservation.

Material Treatments at Towers

Although the conditions observed at the towers are relatively minor compared with cracks documented prior to previous repair campaigns, the existing cracks should be treated as part of an on-going maintenance program to prevent further water intrusion and corrosion of the internal metal elements. Because most of the cracks are hairline width or do not show evidence of severe corrosion and expansion of the internal steel, grouting or patching the cracks to prevent water infiltration without removing large sections of the mortar shell to access the steel armature is appropriate. In cases where there is displacement of the mortar at crack locations or multiple full-width cracks indicating corrosion of the reinforcing, removal of the mortar to inspect and treat the steel is recommended. In developing the specific treatments for the conditions observed, the primary criterion used to determine the appropriate treatment is the waterproofing deficiency of the crack; in this respect, no distinction was made between cracks at original mortar and cracks at areas of repair. The following treatment types were developed to repair the types of conditions described above. Briefly, these repairs are as follows:

- Repair type 1: Inject cementitous grout at hairline crack;
- Repair type 2: Rout crack and install sealant and repair mortar;
- Repair type 3: At crack through embedment, rout crack at mortar and install repair mortar;
- Repair type 4: Remove mortar and embedments, clean and paint reinforcing, patch with repair mortar, and reinstall embedments;
- Repair type 5: Apply penetrating rust inhibitor;

Repair type 1: At most of the hairline cracks, the recommended treatment is to work a cementitous mortar into the crack to fill it. It is difficult to inject grout into thin hairline cracks, but it is possible to force mortar into the cracks to avoid additional removal of material that is usually necessary in most crack repair procedures. The edges of the crack should be masked so that the crack-filling material does not stain or penetrate the surrounding mortar. Then the area of the crack should be moistened and the cementitious mortar worked into the crack with a putty knife or pointing trowel. The patched area should be covered to prevent rapid curing and moistened each day for at least five days.

Repair type 2: Cracks that are currently larger than hairline width typically have some type of movement associated with them, either lateral movement of the towers themselves or the movement of materials due to forces exerted by the expansion of corroding steel. At these cracks, where there are no other signs of continued corrosion, such as displacement at the crack opening, edge spalling along the sides of the crack, or iron staining in the area of the crack, the recommended treatment is to rout out the crack and install sealant and repair mortar. The full width and length of the crack should be routed out, squaring off or undercutting the edges, and a rust inhibitor injected into the routed-out crack, as well as to the surrounding surface of the deteriorated member. Following routing of the crack, a surface-applied rust inhibitor should be injected into the crack using a syringe and applied to the surface of the entire element containing the crack. Sika Ferrogard 903 rust inhibitor was tested in mock-ups at the site and is recommended. The rust inhibitor will form a film on the surface of the mortar after one or two days that must be removed by wire brushing before applying the repair mortar. To address the potential movement that caused the crack initially and provide a flexible seal against water, a sealant should be installed in the routed-out crack. A urethane sealant, such as Sikaflex 15LM, can be used to fill the crack. The sealant should be recessed about 1/4 inch from the surface of the mortar and aggregate broadcast into the sealant while it is still wet. Before the sealant cures, Jahn repair mortar should be installed at the crack. The recommended repair mortar for the Watts Towers is Jahn M90, a single-component, cementitious repair mortar designed for the restoration of concrete. In addition to the standard color, four custom colors of Jahn mortar are recommended to match the red, green, yellow, and grey colors of the existing mortar. Because of the variation in colors of the original mortar, further color matching in the field with oxide pigments will be necessary to more closely match the mortar at each repair area, even if custom-colored Jahn mortars are used. Proper curing of Jahn mortar is essential for its ultimate success; the repair areas should be periodically misted with clean water over the first 72 hours as part of the curing process.

Repair type 3: At cracks that extend through mortar and embedments, the cracked mortar should be treated in the same way as the repair type 2 cracks described above. The cracks through the embedment should not be routed out. As long as the remaining portions of the embedment are sound, the crack should be filled with a material appropriate to the composition of the embedment. At tile, pottery fragments, and shell, Edison Coatings Thin-Fill 55 is recommended. This is a latex-modified, cementitious repair mortar with very fine aggregate, so that it can be worked into the crack through the embedment. Oxide pigments can be added to the Thin-Fill to match the color of the embedment. The latex additive helps to provide adhesion between the repair mortar and the embedment. At cracks through glass, an epoxy-based material, such as Akemi Akepox 2010, is recommended to fill the void and waterproof the crack.

Repair type 4: Cracks associated with signs of active corrosion expansion and deterioration should be cut out to access the internal steel. The mortar shell should be cut out along the crack and at nonornamental areas, where required, to open a window to the steel armature. Where there is embedded ornament at the area of investigation, the mortar shell containing the ornament should be carefully cut out so that the mortar with the ornament can be reset when the repair is completed. Currently, there is no way of knowing how deteriorated the steel is at these conditions, but once the steel is exposed, its condition can be evaluated by a structural engineer to determine whether it can be cleaned and prepared for recovering or whether it should be replaced with a new steel section. Additionally, at each area that is opened up, the project team should determine whether it is appropriate to reinstall the sections of original mortar if removed intact or to install a new mortar repair patch, based on the location, size, and function of the member. Where the steel is sound, all scale and corrosion products should be removed by mechanical wire brushing and the steel treated for patching. Sika Armatec 110 EpoCem, an epoxy resin/Portland cement-based slurry, should be applied in two coats to all exposed metal at the repair area, as well as the mortar surfaces to which the patch is to be installed. This product results in greater bond adhesion between metal and concrete than epoxy coatings or untreated steel, as well as increased protection against corrosion of the metal and does not form a vapor barrier that could trap moisture in the structure. Following preparation of the metal and application of the Armatec, galvanized wire metal lath can be inserted and a mortar mix formulated to match the original Simon Rodia mortar, consisting of 1 part Portland cement to 3 parts aggregate, should be used to patch the area of loss. The mortar patch should be colored using aggregate or pigments to match the color of the original mortar.

Where the steel is determined to be deteriorated beyond the point of function, the steel armature should be exposed as far as necessary to locate sound steel. Once sound steel is identified, the deteriorated section of metal should be cleaned and prepped, and new mild steel welded in place to replace the original steel. The repair area should then be covered with the Armatec protective coating and the entire area patched.

Several types of galvanic protection were investigated by ARG for the potential incorporation into the recommended repair program. The most effective galvanic protection system is generally cathodic protection in which an electron current is introduced into the structural system to overcome the loss of electrons that occurs during the corrosion process. The current can be applied either globally from a direct-current source or at discrete locations using anodes that are inserted into the structure and connected to a power source. In the case of the Watts Towers, the discontinuity between internal steel elements and the use of other metals, such as copper and lead, within the armature makes a global, direct-current, galvanic system ineffective. The anodes typically used for providing cathodic protection to discrete areas are relatively large and could not be installed at areas of repair.

Another type of cathodic protection system that is becoming more common with concrete repairs at cultural resources is to install a sacrificial anode at the area of repair to prevent corrosion of steel within and adjacent to the repair area. The anode is embedded in the repair and does not require an external power source. The sacrificial anodes, such as Sika's Galvashield XP Anode, consist of a zinc core surrounded by a cementitious mortar with wire ties for attaching the anode to the existing steel. The zinc core takes the place of the anode, or corroded area of steel, in attracting the electrons that lead to further corrosion. The mortar shell maintains the alkaline environment of the system to reduce corrosion. Although standard size anodes would be too large to fit within most of the repairs of the members of the towers, custom-sized anodes ½ inch thick and 2 inches long by 1-3/8 inches wide can be manufactured in a minimum order of 1,000 anodes. Although most of these anodes would not be used in the current repair program, they could be stored and used in future repairs as required.

Repair type 5: At some areas, iron staining is visible on the mortar surface, although there are no cracks or wire mesh visible at the surface of the mortar shell. At these locations, the recommended treatment is to brush or spray-apply a penetrating rust inhibitor to the surface of the mortar in an area extended 12 inches beyond the size of the condition. This is a preventative treatment to deter the continued corrosion of the metal that is causing the iron staining or visible at the surface. The recommended rust inhibitor is Sika Ferrogard 903.

Material Treatments at Ornamental Floor

The concrete flooring is generally soiled, especially in areas that do not drain properly or are protected from the rain. All concrete flooring should be cleaned using a warm, low-pressure water rinse to remove all soiling. Following cleaning, the cracks and spalls in the concrete floor should be treated. The recommended treatments for each of the conditions observed on the ornamental concrete floor surfaces are summarized below.

- Repair type 6: Inject epoxy through cracks at voids in ornamental floor;
- Repair type 7: Rout crack and install repair mortar at ornamental floor;
- Repair type 8: Remove deteriorated material at edge of spall, install repair mortar at spall locations on ornamental floor.

Repair type 6: At the voids between the slab layers at the ornamental floor, port holes should be drilled at existing cracks or score lines where they exist and epoxy injected into the voids. A high-modulus, low-viscosity epoxy injection grout, such as Sikadur 35, Hi-Mod LV LPL is recommended. After drilling the port holes and sealing all cracks and other openings where the grout might escape, the epoxy grout would be injected into the void using low pressure. Two passes of epoxy injection are recommended to insure that the injected material remains in the void and is not absorbed into the ground. Epoxy gel or other materials that require high-pressure injection are not recommended because the injection process may damage the floor or other materials. Following curing of the epoxy, the port holes and cracks at the void would be patched as described below for repair types 7 and 8.

Another repair considered for treating hollow areas at the ornamental floor is to cut out the slab at the voids and reinstall the original piece following treatment. If the void is between the ground and the first concrete slab, new compacted soil may be necessary to fill the void. If the hollow sound is due to separation between the slab layers, the layers could be readhered using an epoxy that acts as a filler and adhesive. This repair is not recommended, however, because removing and reinstalling the numerous areas of concrete where voids were detected would leave an obvious pattern of repair that would detract from the visual appearance of the original floor.

Repair type 7: Cracks that are larger than hairline cracks should be repaired to prevent water infiltration into the slab, and to prevent potential tripping hazards. Most of the cracks are not wide, but extend for long lengths. Some of the cracks also have small chipping or other deterioration at the edge of the crack. The first step is to rout out the crack its entire length to a depth and width of at least ¼ inch using a variable-speed rotary tool, such as a Dremel, a masonry grinder and hand tools. The edges of the routed crack should be squared or undercut to provide a mechanical key for the repair mortar. If the crack also has some displacement, rout out the entire area around the displacement. The recommended repair mortar for the Watts Tower is Jahn M90, a single-component, cementitious repair mortar designed for the repair of concrete. The color of the repair mortar should match the existing original concrete. The color matching will have to take place in the field because the color of the concrete varies so dramatically within each floor area. If a crack spans across a patterned area of the concrete, the pattern should be recreated to match the original. The crack repair areas should be periodically misted with clean water over the first 72 hours as part of the curing process.

Repair type 8: The spalls in the concrete flooring tend to be small but require repair to prevent them from becoming larger. The first step is to remove all unsound material around the spall to a minimum of ¼ inch into sound material. The edges of the repair should be squared or undercut to provide a mechanical key for the repair mortar. Jahn M90 is also recommended for spall repair. The color of the repair mortar should match the color of the existing original concrete. This color matching will have to take place in the field due to the variety of colors in the concrete flooring. Install the repair mortar in lifts, allowing each lift to cure slightly before installing the next lift. The final lift should be textured to match the adjacent concrete and misted with clean water over the first 72 hours as part of the curing process.

Phase II Deliverable Products

The documentation, research, analysis, and repair work to be performed as part of Phase II in the Watts Towers Fissures project should be considered another phase in the continuing evaluation and treatment of the towers. The database and graphic documentation created following the synthesis of the existing documentation and results of testing and analysis done on proposed materials and mock-ups should be appended to the first comprehensive study of the Watts Towers prepared by the Ehrenkrantz Group. An updated maintenance manual designed for consultation and use on-site should also be included with the deliverables for Phase II.

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Kariotis & Associates. "Report of Third Party Review of Watts Towers." August 12, 2003. Photocopy.

Whalen, Tim. Letter to Ted Jackson, California State Parks. October 14, 2003.

Whiteson, Leon. *The Watts Towers of Los Angeles*. Oakville, Ontario: Mosaic Press, 1988.

APPENDIX A: Photographs of Typical Conditions

The following photographs were taken by Architectural Resources Group between September 30 and October 12, 2004. The photographs illustrate the typical conditions identified during ARG's fieldwork.

Figure 1: View looking southwest of West Tower from boom lift.

Figure 2: View looking southeast of Center Tower and East Tower from boom lift.

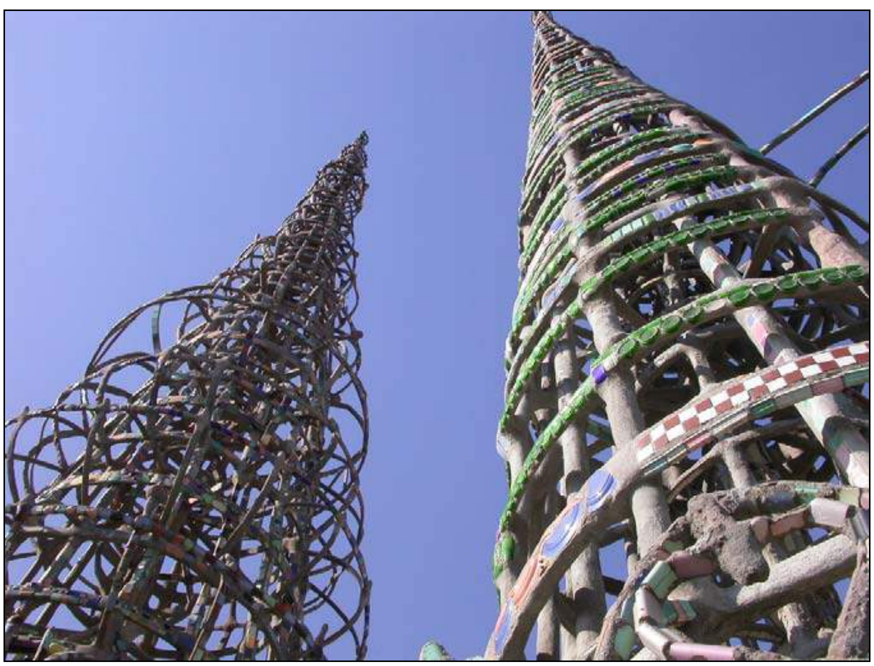

Figure 3: View of West and Center Towers looking northwest from ground.

Figure 4: Hairline crack on Center Tower at intersection between exterior column and brace in an area of previous repair.

Figure 5: Crazing at previous repair on West Tower at bottom of exterior column.

Figure 6: Crack on Center Tower at base.

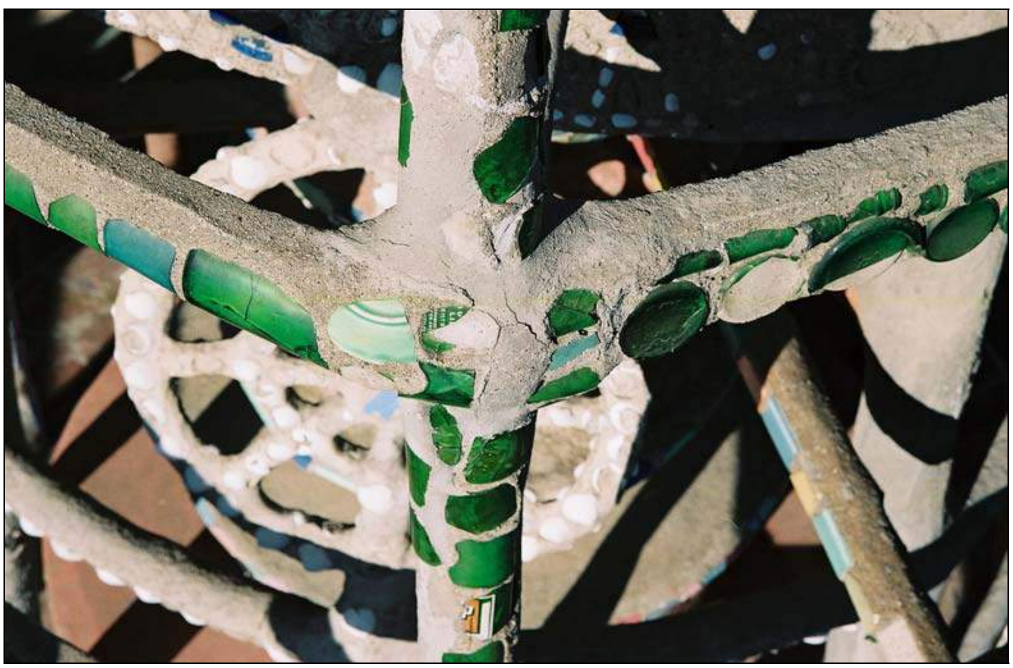

Figure 7: Crack on East Tower at intersection between of exterior column and exterior band.

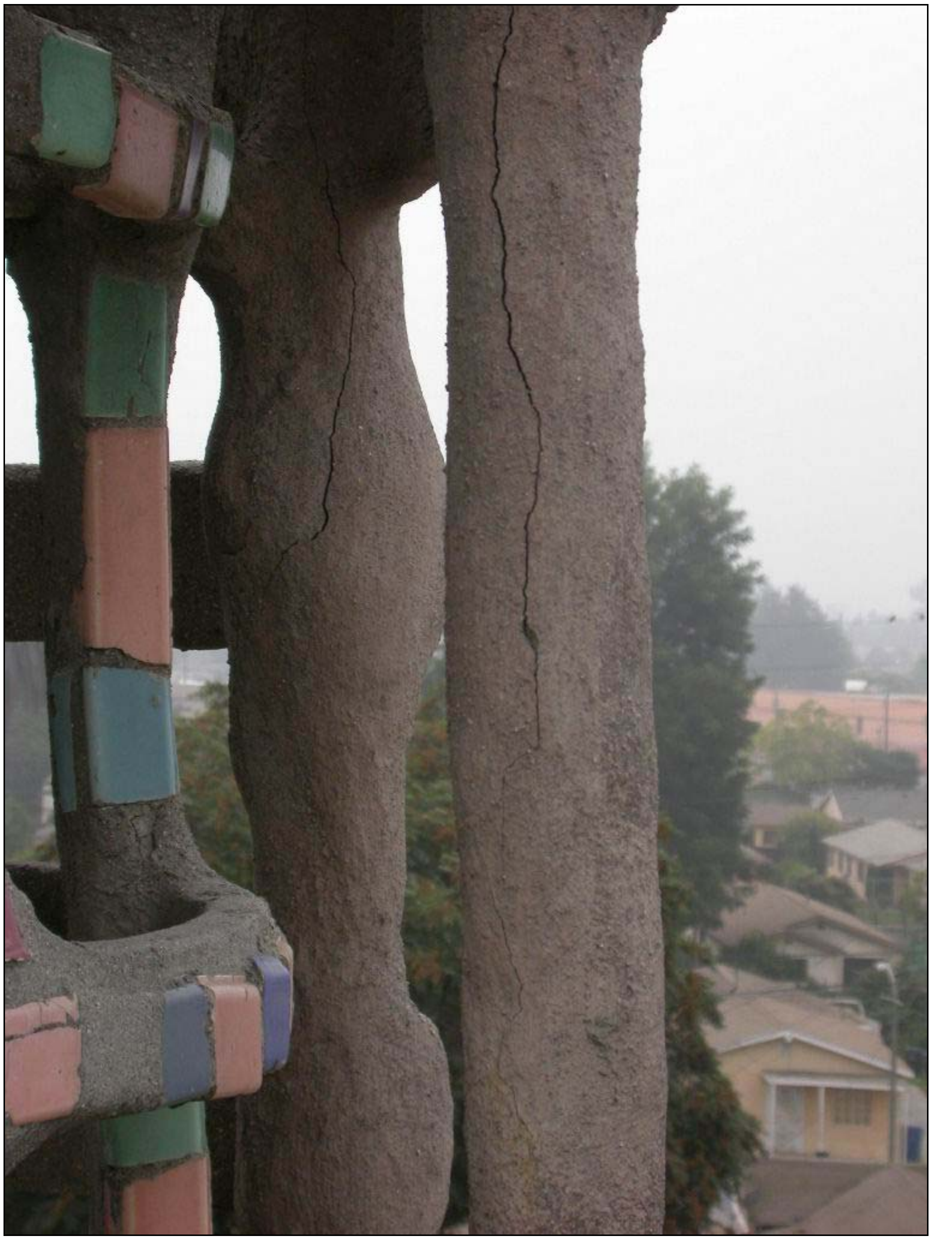

Figure 8: Crack on Center Tower at exterior column in an area of previous repair.

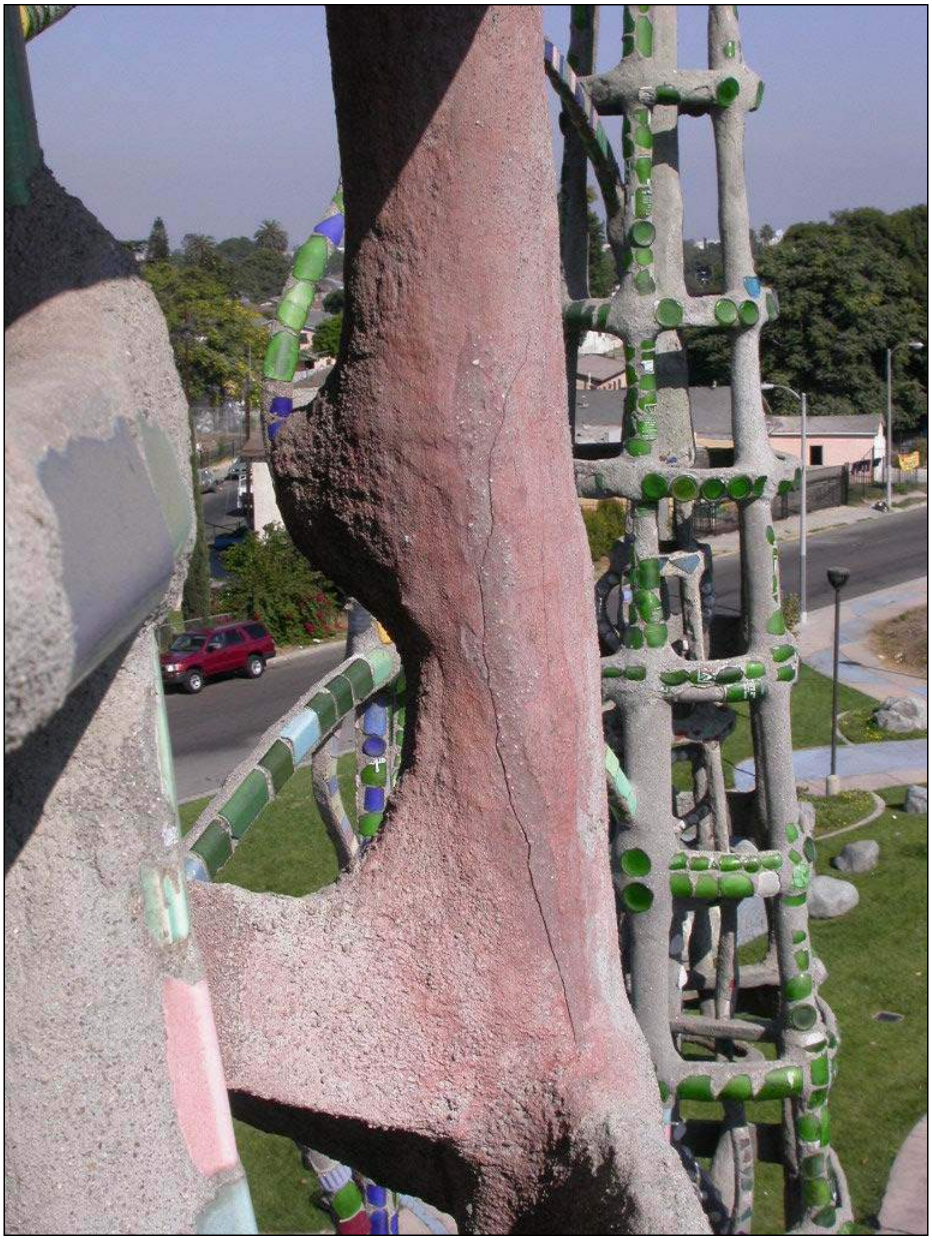

Figure 9: Cracks on Center Tower at exterior columns.

Figure 10: Crack on West Tower at loop that has been partially cut out.

Figure 11: Crack through shell embedment on West Tower at exterior column showing iron staining at bottom of crack.

Figure 12: Cracks on East Tower at exterior column through glass embedment.

Figure 13: Exposed wire mesh at bottom left of embedded cup on Center Tower.

Figure 14: View of south elevation of Center Tower showing different mortar colors used.

Figure 15: Cable bracing at Center Tower.

Figure 16: Weep hole at bottom of exterior column at Center Tower.

Figure 17: Carbonation test on band of East Tower.

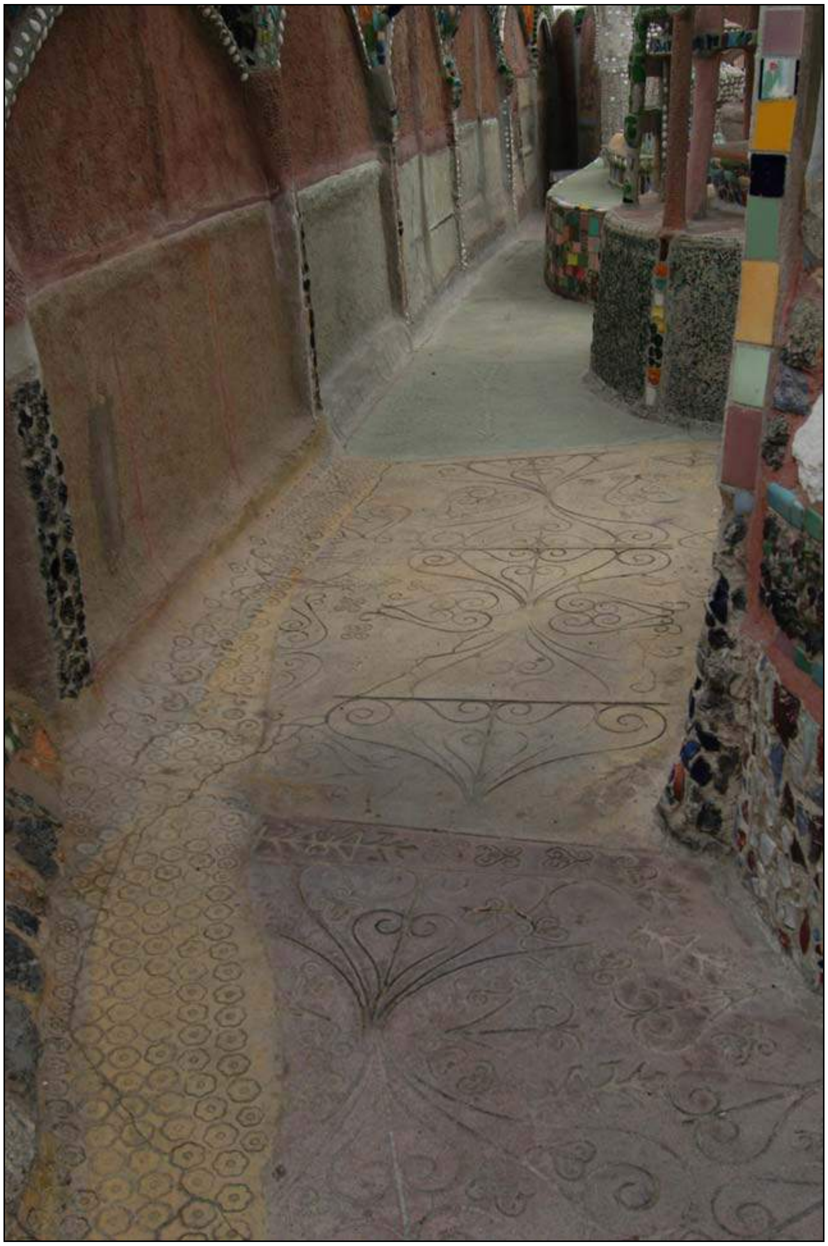

Figure 18: Ornamental floor on the north side of the towers showing red-, yellow-, and green-colored concrete slab with stamped patterns.

Figure 19: Floor at northwest corner of site showing crack with displacement and previous repair.

Figure 20: Crack through green colored concrete that has been previous repaired.

Figure 21: Floor at south side of Center Tower with crack circling the perimeter of the tower approximately 2 feet from the base.

Figure 22: Spall at edge of score line in concrete floor.

Figure 23: Patch (bottom of photograph) at red-colored concrete floor.

APPENDIX B: Photographs of Repair Mock-ups

The following photographs were taken by Architectural Resources Group on November 8 and 9, 2004. The photographs illustrate the before and during conditions of the mock-up repairs. The mock-ups will be evaluated as part of Phase II of the Watts Towers Fissures project.

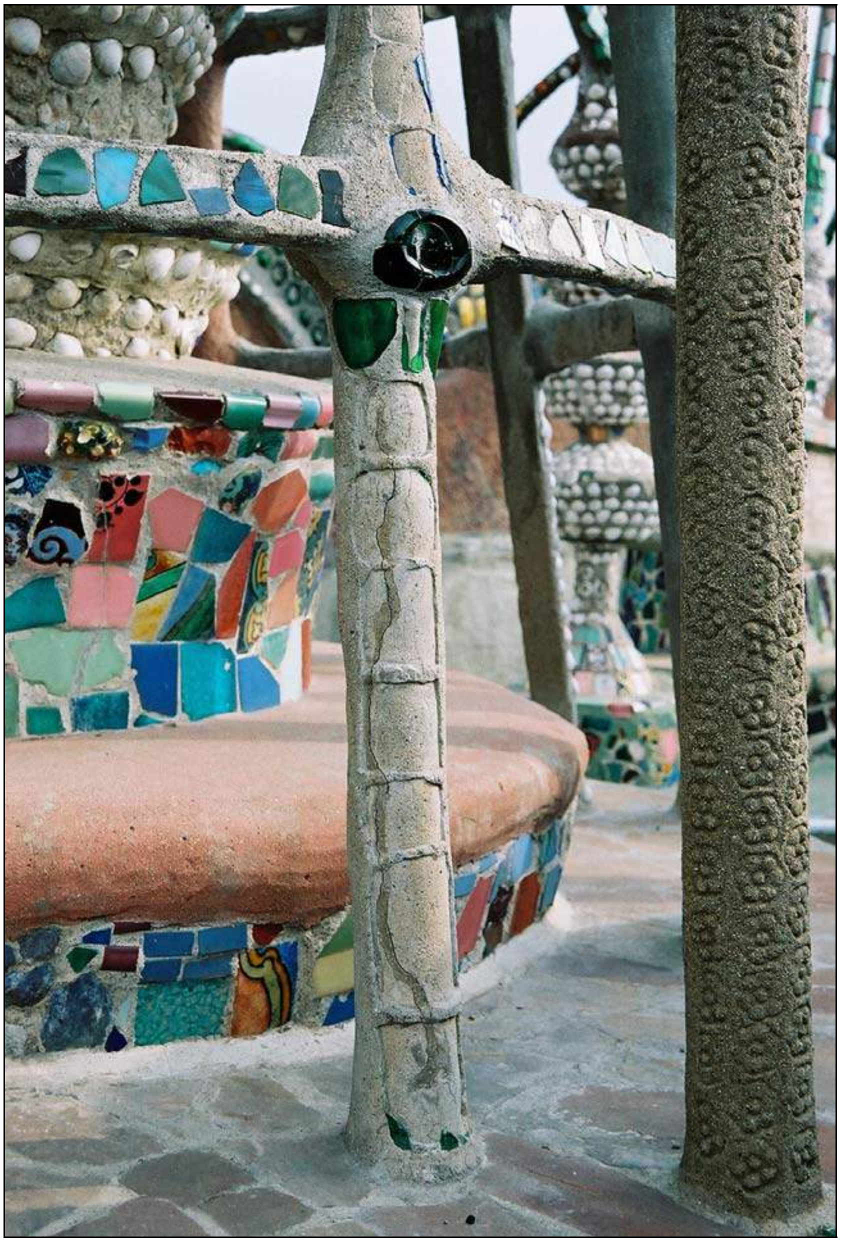

Figure 1: Mock-up no. 1 at intermediate column on south side of the East Tower before cutting out. The darker color mortar at the vertical crack is from a previous repair.

Figure 2: Cutting out of mortar of previous repair using hand tools at mock-up no. 1.

Figure 3: Application of Ferrogard 903 rust inhibitor to cut out crack at mock-up no. 1.

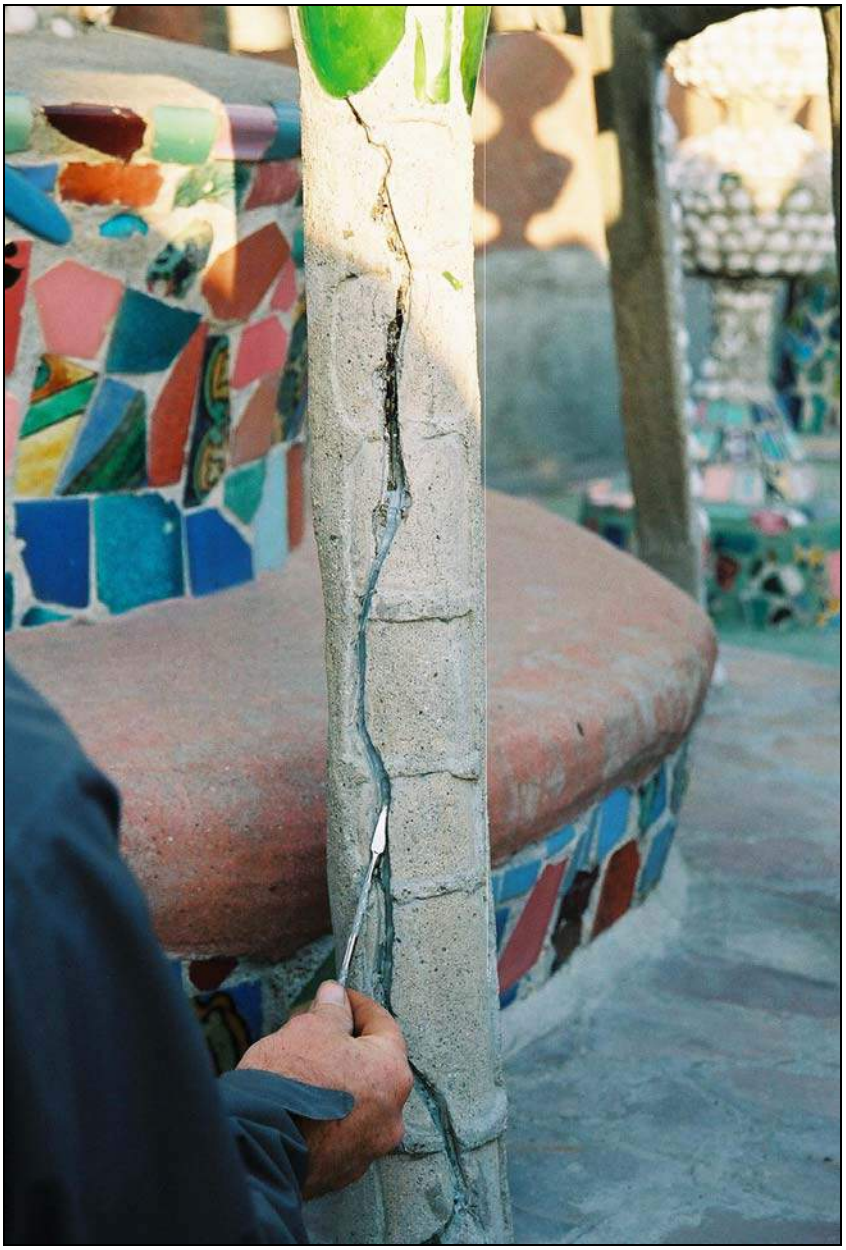

Figure 4: Mock-up no. 1 during application of sealant at middle of crack and epoxy resin at bottom of crack.

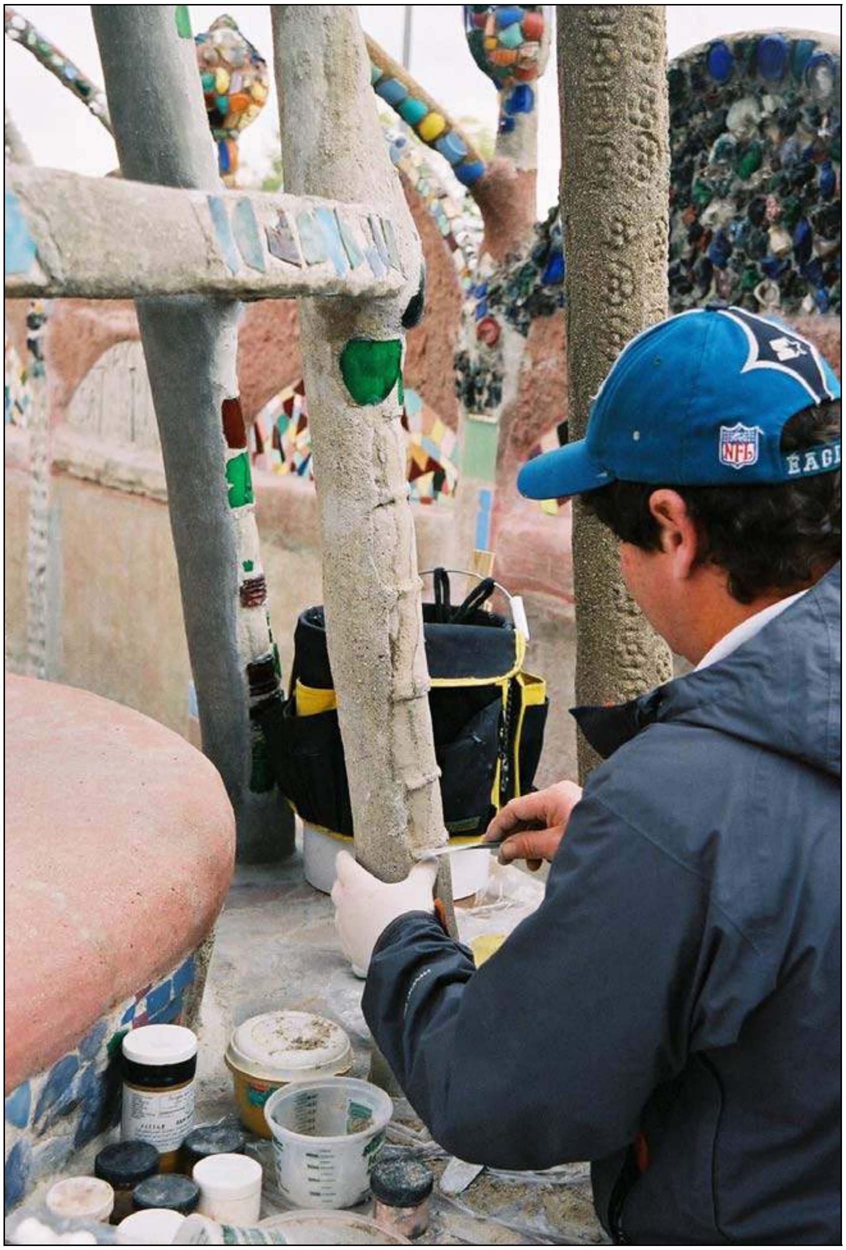

Figure 5: Mock-up no. 1 during application of Jahn M90 repair mortar.

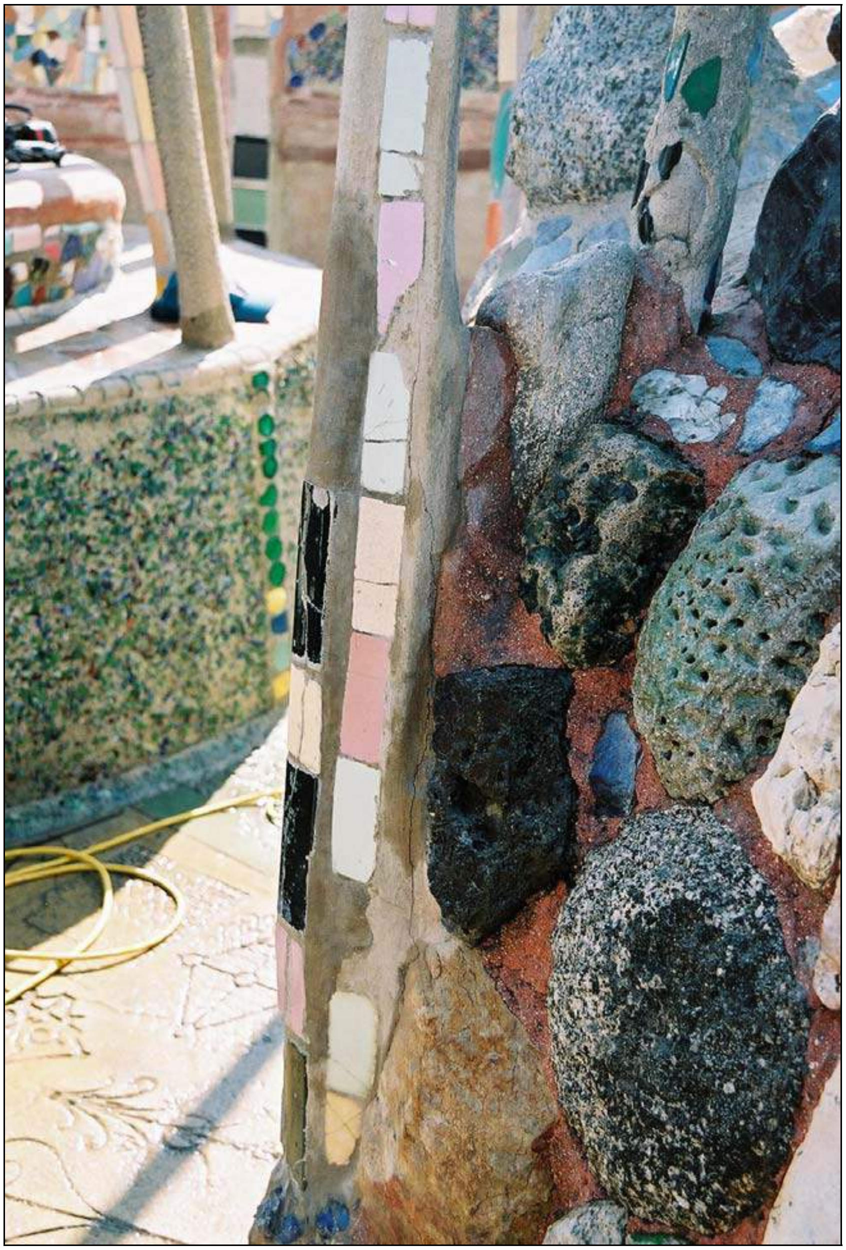

Figure 6: Mock-up no. 2 on north-facing side of exterior column at Center Tower.

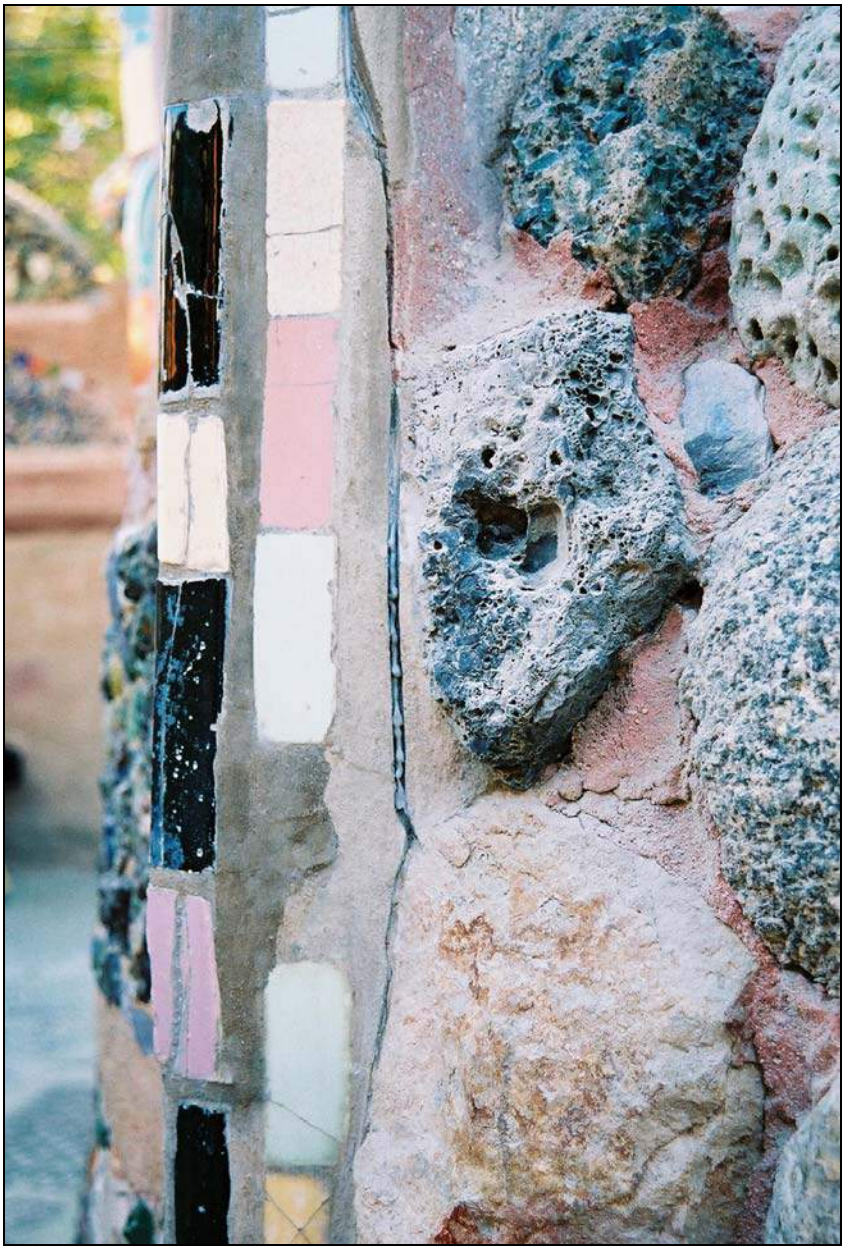

Figure 7: Mock-up no. 2 showing sealant at cut-out section of crack repair.

Figure 8: Installation of pigmented Jahn M90 repair mortar at mock-up no. 2.

Figure 9: Mock-up no. 3 at west side of green base level of West Tower before treatment.

Figure 10: Cutting out of crack at mock-up no. 3.

Figure 11: Mock-up no. 3 after installation of pigmented Jahn M90 repair mortar.

Figure 12: Mock-up no. 4 at west side of red base level of West Tower before treatment.

Figure 13: Mock-up no. 4 during installation of pigmented Jahn M90 repair mortar.

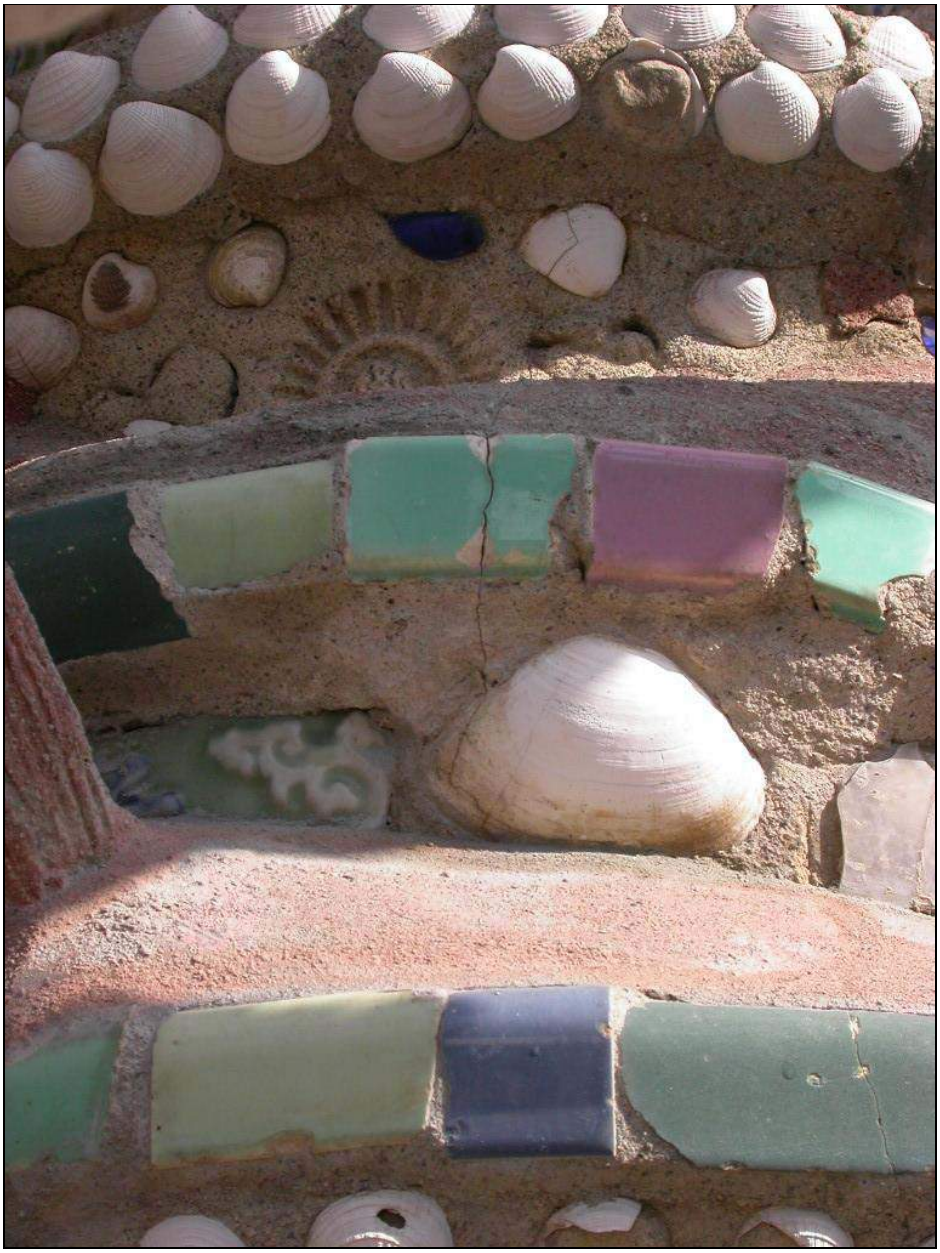

Figure 14: Mock-up no. 5 at center core of East Tower showing crack through mortar and embedded tile before treatment.

Figure 15: Mock-up no. 5 after cutting out of crack at mortar.

Figure 16: Mock-up no. 5 after installation of Jahn M90 repair mortar at mortar and Edison Coatings Thin-Fill 55 at tile.

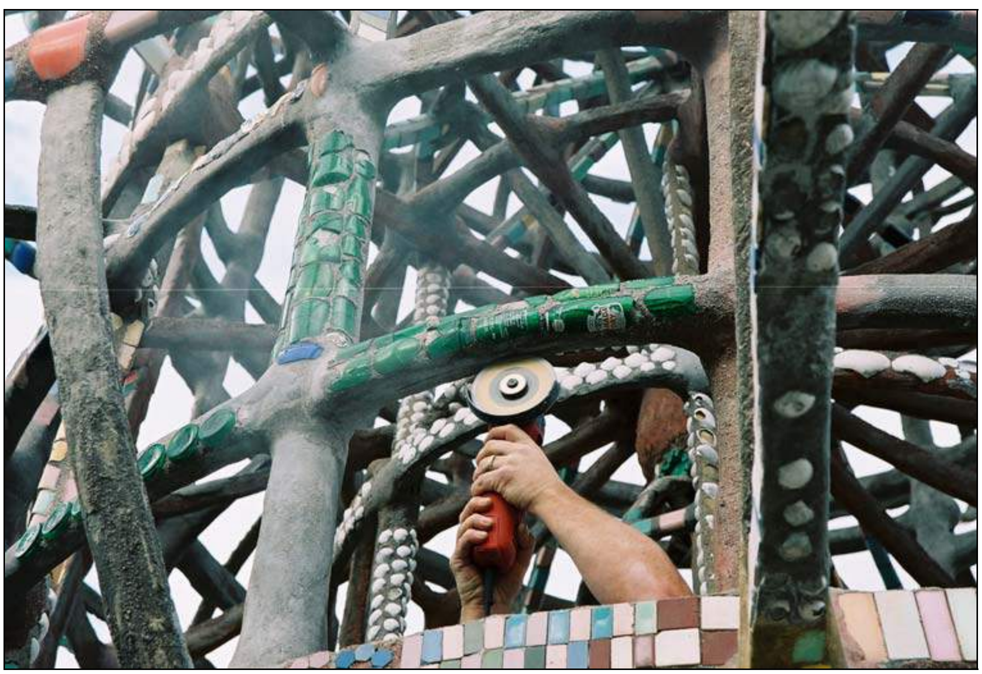

Figure 17: Cutting of crack at bottom of exterior band on West Tower.

Figure 18: Original steel armature at exterior band on West Tower, as viewed from the interior face.

Figure 19: Removed sections of concrete at edge of base level on south side of West Tower.

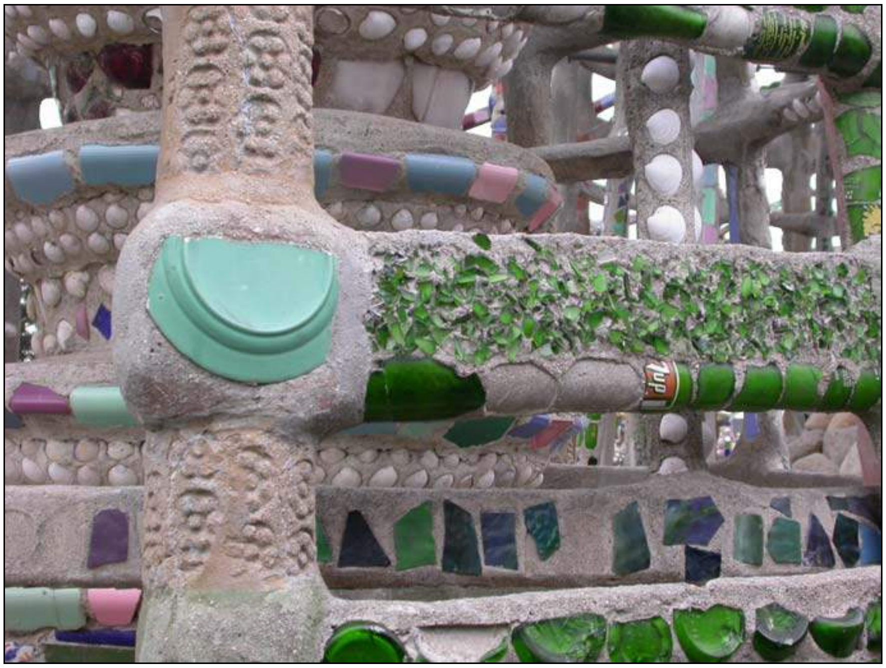

Figure 20: Water repellent mock-up location on north side of East Tower before treatment application.

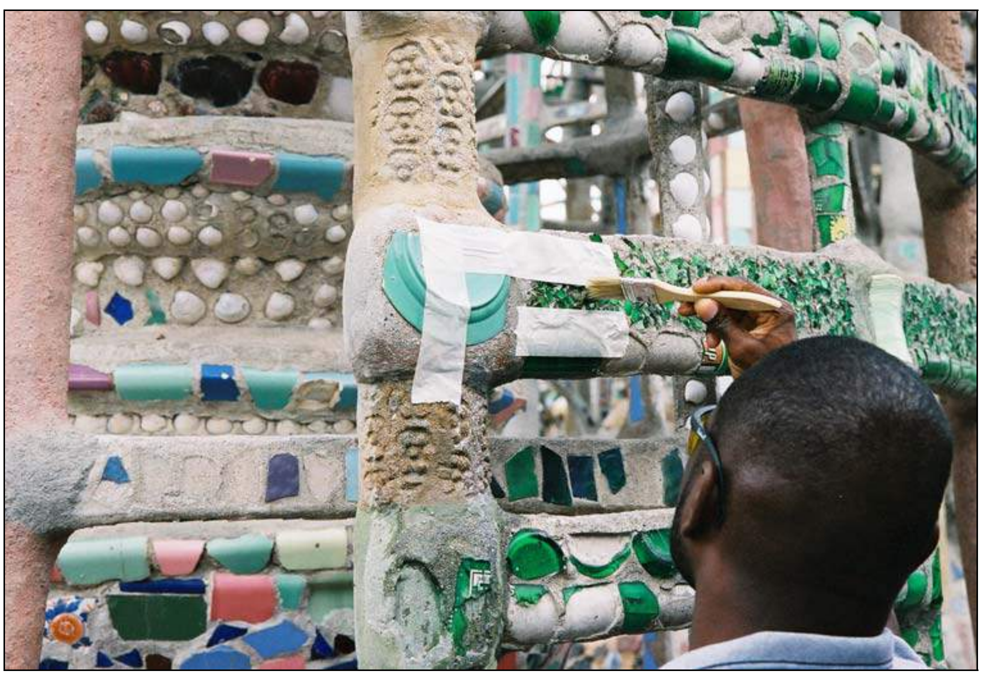

Figure 21: Mock-up location during application of water repellent.

Figure 22: Samples of mortar and reinforcing previously removed from towers used for testing application of water repellent and penetrating rust inhibitor before treatment.

Figure 23: Sample following treatment, with rust inhibitor at the left of the large sample, no treatment at the center, and water repellent applied to the right.

APPENDIX C: List of Tested and Proposed Materials

This appendix lists the manufacturers of the materials discussed in the preceding report that were either tested or are proposed for further testing for use in the conservation of the Watts Towers. Also included are product information and material safety data sheets where applicable for the products.

Jahn M30,Jahn M90
Manufacturer/Distributor:
Cathedral Stone Products, Inc.
7266 Park Circle Drive
Hanover, MD 21076
(800) 684-0901
www.jahnmortars.com

Thin-Fill 55 Masonry & Concrete Thin-Section Reprofiling Mortar
Manufacturer/Distributor:
Edison Coatings, Inc.
3 Northwest Drive
Plainville, CT 06062
(860) 747-2220
www.edisoncoatings.com

Sikadur 23 Lo-Mod Gel, Sikaflex 15LM, Sika Armatec 110 EpoCem, Sika Galvashield XP, Sika FerroGard 903, Sikagard 701W, Sikadur 35 Hi-Mod LV LPL
Manufacturer/Distributor:
Sika Corporation
201 Polito Avenue
Lyndhurst, NJ 07071
(800) 933-7462
www.sikausa.com

APPENDIX D: Degenkolb Structural Evaluation Report

The following report prepared by Degenkolb Engineers discusses the structural conditions and recommendation for the Watts Towers.

Degenkolb Engineers

225 Bush Street, Suite 1000
San Francisco, CA 94104-4207
Phone: 415.392.6952
Fax: 415.981.3157

Memorandum

DRAFT

Date	November 16, 2004	**Job**	Watts Tower
To	Evan Kopelson	**Job Number**	A4114020.00
	ARG	**Subject**	Summary of Investigation
From	Raymond S. Pugliesi		

Report:

This report summarizes my findings on the condition and structural behavior of the three main towers and site slab on grade at the Watts Towers National Monument. This investigation was very limited in nature and consisted on two site visits and a general review of available documentation.

On September 16 and October 13, 2004 I visited the Watts Towers site to review the three large towers and the concrete slabs on grade. On the later visit, a large boom lift was available that enable me to view the entire heights of the towers up close. During my site visits I was also able to discuss the behavior and history of the towers as well as the current and past repair techniques being used by the staff. The following is a summary of my findings and general recommendations.

Structural Condition:

My observations of the exterior mortar shell of the three tower structures found them to be in very good condition. The limited number of cracks that were observed was in general of small widths, with only a few large cracks, estimated over 1/16", but were short lengths. There were no locations observed that showed signs of cracking or corrosion indicative of an immediate falling hazard of the mortar.

In review of the Preservation Plan by The Ehrenkrantz Group, it was indicated that the existing mortar has high chloride levels. The presence of chlorides can accelerate deterioration of the steel armature. The report only has limited mention of the evaluation of the chloride levels and is rather old information. We recommend that this be better defined. If the levels are indeed high, the corrosion of the steel could be much more difficult to control than simply keeping the water out and may warrant investigating other techniques such as cathodic protection.

Signed Raymond S. Pugliesi

Copies to

The towers have a few locations with what looks like provisions for draining the interior center core column. We understand through descriptions of previous repairs, that there have been instances where steel pipe was found inside the columns and were filled with water. To reduce the corrosion of the steel, the water must have a path out of the structure should it get in. We recommend that where there are pipes used in the structure that could hold water that provisions be installed to allow free draining of any water that intrudes into the armature. In addition, any drain pipes that are currently installed should be verified that they are clear and operable.

The towers have been strengthened with the installation of radial cable restraints at multiple levels. Observation of this system found the cable restraints rusting and that the turnbuckles used have open-ended hooks at each end. The corrosion of the restraints poses an immediate staining hazard to the monument as it slowly deteriorates away and eventually will not serve its purpose to bind the cable. The open ends of the turnbuckles may indicate a low quality item. The failure mode of similar items will bend the hook open as they are loaded, possibly releasing the cable. Increased loading demands on the turnbuckles will be experienced during lateral forces such as wind or earthquake when the axial loads on the column legs increase due to overturning. We recommend the cable clamps be replaced with one that is hot dipped galvanized and the turnbuckle replaced with a closed welded end model or possible evaluated to determine if they are adequate as is. During the replacement, the cables can be re-tensioned as they likely have relaxed over time.

Documentation:

The Watts Towers have a long and extremely intriguing history. Part of that history consists of the repair and maintenance of the work and then eventually its conservation effort. Documentation of the repairs has been made, however, access to and use of this information is extremely limited; primarily due to the sheer volume of information. From a structural standpoint, the information could be much better organized to assist with future evaluations of the Watts Towers. I believe it would be a benefit to slowly document a model of each tower, identifying each area of repair and the parameters found in each area. As a minimum this should list the thickness of the mortar, the mortar properties, the steel pieces found in the element, and the repair done. This should be of benefit for any future analyses of the structures.

Signed Raymond S. Pugliesi

Copies to

Repair Techniques:

In the past, The California Department of Parks has very wisely enlisted the services of qualified structural engineers in their assessments and repair procedures. On my first site visit, I met with Mel Green who seemed to have a very good understanding of the history as well as the behavior of the structures. I highly recommend continuing the use of a structural engineer in the ongoing repairs and investigations. I understand that a repair technique is warranted for the Conservation Handbook, but think it should be further extended to seek the review by a structural engineer prior to the repair of major elements of the structure and any repairs that require replacement of the structural steel armature. In addition, periodic observation by the structural engineer would be advantageous during the major repairs.

Currently any distress that leaves large portions of the mortar shell in tack are repaired by re-applying the mortar piece to the steel armature. This technique results in a structural assemblage much different than the original construction. Originally, the use of steel, wire, and mortar has created a composite reinforced mortar structure that is very much like reinforced concrete. However, this type of repair is very unlikely to achieve a good bond between the steel and mortar and could lose the composite action. The structure then must rely only on the steel skeleton at this location. I recommend this be more closely examined to determine whether this is acceptable. For instance, on the low stressed or highly redundant elements, this loss in strength may be acceptable. Also, due to the highly favorable conservation aspects of this technique, I think it would be most appropriate to determine the applicability of this technique on a case-by-case basis rather than not allow it for any locations. Alternately, with more investigation, it may be possible to better define what areas are acceptable and which specifically should be evaluated on a case-by-case basis.

Although the towers have been evaluated in the past, each repair to the structure alters it a little. Since much is learned about the composition of the tower after each repair, and in some cases is modified either through strengthening of the steel armature or repairs of the mortar, it could prove worthwhile to start developing computer analysis models of the towers for detailed evaluations. For instance, stress investigations could assist in determining whether the steel armature, although reduced in cross section, really needs to be replaced or just reconditioned. The model could also serve for more state of the art dynamic seismic analysis.

Concrete Slabs on Grade:

The site slabs-on-grade has many cracks and was evaluated by others to likely be multiple layers that are delaminated in many locations. Along the center tower there appears to be a very small crack that encircles the base of the tower. This is presumably mirroring the extent of the foundation/soil interaction from movement of the tower. Because the crack shows no vertical offset and there are no other signs of settlement along the towers, I do not believe this should be considered excessive movement, ie such as vertical settlement or rocking due to lateral wind or earthquake loads, and should not be of concern. I also do not believe foundation movement is contributing to the majority of other slab cracks on the site.

Signed Raymond S. Pugliesi

Copies to

The thinness of the slabs leads me to believe they are likely not reinforced or are very lightly reinforced. Once cracked, the slab is then unrestrained at the crack and can offset as witnessed in a number of locations. This can create a tripping hazard and of coarse is much more visually objectionable then a small hairline crack with no vertical offset. The delaminating of the slab layers could be contributing to the resulting cracking. As the slab delaminates the upper and lower thin slab layer is much more susceptible to cracking. For instance, if the slab delaminates into two equal layers, the layer become one quarter of the original bending strength. The intrusion of water through cracks into the sandwich between the layers will further deteriorate the bond between the layers and will further delaminate the slab. This could explain one reason why new cracks are being discovered. The slab is primarily loaded by a number of conditions including the foot traffic, construction traffic, and ongoing temperature changes. To resolve the delaminating we recommend investigating an epoxy injection technique to mend the layers together. Through careful execution, it should be possible to inject the area through ports in existing cracks. Care will need to be taken to avoid lifting the slab due to the viscosity and/or volume of the media injected as well as simply monitoring the extent of injection below the slab.

One initial thought of why the slab was cracking was possibly due to heaving and swelling of the underlying and surrounding soils due to surface water infiltration. Based on the soil report for the neighboring amphitheatre construction, there were many borings that indicate the soil is primarily sandy in the upper layers. This soil type would not exhibit swelling behavior due to water. There are problems, however due to the erosion effects of water runoff. At one location, the runoff by surface water at the rear northwest corner of the original house has caused erosion of the soil; resulting in settlement and cracking of the slab. We recommend that all surface runoff water be evaluated and controlled.

Signed Raymond S. Pugliesi

Copies to

Degenkolb Engineers

225 Bush Street, Suite 1000
San Francisco, CA 94104-4207
Phone: 415.392.6952
Fax: 415.981.3157

Memorandum

Date	November 19, 2004	**Job**	Watts Tower
To	Evan Kopelson	**Job Number**	A4114020.00
	ARG	**Subject**	Summary of Investigation
From	Raymond S. Pugliesi		

Report:

This report summarizes my findings on the condition and structural behavior of the three main towers and site slab on grade at the Watts Towers National Monument. This investigation was limited in nature and consisted of two site visits and a general review of available documentation.

On September 16 and October 13, 2004 I visited the Watts Towers site to review the three large towers, and the concrete slabs on grade. On the later visit, a large boom lift was available that enable me to view the entire height of the towers up close. During my site visits I was also able to discuss the construction, behavior, and history of the towers as well as the current and past repair techniques being used by the staff. The following is a summary of my findings and general recommendations.

STRUCTURAL CONDITION:

The exterior mortar shell of the three tower structures appears to be in very good condition. The cracks that were observed were of small widths, with only a few large cracks (estimated over 1/16" wide), of short lengths. There were no signs of cracking or corrosion indicative of an immediate falling hazard of the mortar.

Mortar Chloride Level:

A review of the *Preservation Plan* by The Ehrenkrantz Group, indicates that the existing mortar has high chloride levels. The report only has limited mention of the evaluation of the chloride levels and is rather old information. We recommend that this be better defined, since the presence of chlorides can significantly accelerate deterioration of the steel armature. In addition, if the chloride levels are indeed high, the corrosion of the steel could be much more difficult to control than by simply keeping the water out and may warrant investigating other rehabilitation techniques such as cathodic protection.

Signed Raymond S. Pugliesi

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Water Intrusion into the Steel Frame:

We understand through descriptions of previous repairs that there has been instances where steel pipe reinforcing was found filled with water inside the tower columns. To reduce the corrosion of the steel, intruding water must have a path out of the structure. The three towers have a few locations with what looks like provisions for draining the interior center core column. We recommend all pipes or tubes used in the structure that could hold water have provisions installed to allow free draining of any water that intrudes into the armature. In addition, the drains that are currently installed should be verified that they are clear and operable.

Cable Restraints:

The towers have been strengthened with radial cable restraints at multiple levels. My observations found the cable restraints rusting and turnbuckles with open-ended hooks at each end. The corrosion of the restraints poses an immediate staining hazard to the monument, and eventually they will not serve to bind the cable. The open ends of the turnbuckles may indicate a low quality item. The failure mode of the turnbuckles will bend the hooks open, as they are loaded, possibly releasing the cable. Lateral forces such as wind or earthquake will increase loading demands on the turnbuckles when the axial loads on the column legs increase due to overturning loads. We recommend that the cable clamps be replaced with new hot dipped galvanized pieces and the turnbuckles replaced with closed welded end models or possible evaluated to determine if they are adequate as is. During the replacement, the cables should be re-tensioned as they likely have relaxed over time.

Documentation:

The Watts Towers have a long and extremely intriguing history. In addition to their unique construction, they have been repaired and maintained since the beginning and now continues through their conservation. Documentation of the repairs has been made; however, access to and use of this information is extremely limited primarily due to the volume of information and lack of useable indexing and access.

From a structural standpoint, the information could be better organized to assist with future evaluations of the Watts Towers. We believe it would be a benefit to thoroughly document each tower, identifying each area of repair and the parameters found in each area. As a minimum, this should list the thickness of the mortar, the mortar properties, the steel pieces found in the element, and the repair done. This would be of benefit for any future analyses of the structures.

Signed Raymond S. Pugliesi

Copies to

Repair Techniques:

In the past, The California Department of Parks and the City of Los Angeles has very wisely enlisted the services of qualified structural engineers in their assessments and repair procedures. On my first site visit I met with Mel Green who seemed to have a very good understanding of the history as well as the behavior of the structures. We highly recommend continuing the use of a structural engineer in the ongoing repairs and investigations. We understand that a repair technique is needed in the updated Conservation Handbook, but think it should also require review by a structural engineer prior to the repair of major elements of the structure and any repairs that require replacement of the structural steel armature. In addition, the structural engineer should perform periodic observation during the major repairs.

Originally, the use of steel, wire, and mortar has created a composite reinforced mortar structure that is very much like reinforced concrete. Currently any distress that allows large pieces of the mortar shell to be removed undamaged is repaired by re-applying the original mortar piece to the steel armature. This technique results in a structural assemblage much different than the original construction. This type of repair is likely to result in a poor bond between the steel and mortar with loss of the composite action. The structure then must rely only on the steel skeleton at this location. We recommend this be more closely evaluated to determine whether this is acceptable. Due to the highly favorable conservation aspects of this technique, we think it would be most appropriate to determine the applicability of this technique on a case-by-case basis. Alternately, with more analysis of the structures, it may be possible to better define what areas are acceptable, which are unacceptable, and which should be evaluated on a case-by-case basis.

Although the towers have been evaluated in the past, each repair to the structure alters it slightly. Since much is learned about the composition of the tower during each repair, and in some cases the structure is modified either through strengthening of the steel armature or repairs of the mortar, it could prove worthwhile to start developing computer analysis models of the towers for detailed evaluations. Structural analyses of the towers would assist in determining whether the steel armature, although probably reduced in cross section, needs to be reconditioned, strengthened, or replaced with a similar or larger member. The model could also serve for more state of the art dynamic seismic and wind analyses. The ability of available computer analysis programs could quickly assist in evaluating the demands on each element of the tower and once the analysis model is completed it could be utilized many times over for each repair investigation.

Concrete Slab on Grade:

The site slab-on-grade has many cracks and was evaluated by others to likely be multiple layers that are delaminated in many locations. Around the center tower there appears to be a very small crack that encircles the base of the tower. This is presumably mirroring the extent of the foundation/soil interaction from movement of the tower. Because the crack shows no vertical offset and there are no other signs of settlement along the towers, we do not believe this should be considered excessive movement, such as vertical settlement or rocking due to lateral wind or earthquake loads, and should not be of major concern. We also do not believe foundation movement is contributing to the majority of other slab cracks on the site.

Signed Raymond S. Pugliesi

Copies to

The thinness of the slabs leads us to believe they are likely not reinforced or are very lightly reinforced. Once cracked, the slab is unrestrained at the crack and can offset as witnessed in a number of locations. This can create a tripping hazard and is more visually objectionable then a small hairline crack with no vertical offset. The delaminating of the slab layers could be contributing to the resulting cracking, once the slab delaminates, the upper and lower thin slab layers are much more susceptible to cracking. If the slab delaminates into two equal layers, each layer become one eighth of the original bending strength. The intrusion of water through cracks into the sandwich area between the layers will further deteriorate the bond between the layers and will further delaminate the slab. This could be one reason why new cracks are being discovered.

The slab is loaded by a number of conditions including the foot traffic, construction traffic, and ongoing temperature changes. To repair the delaminating, we recommend investigating an epoxy injection technique to bond the layers together. Through careful execution, it should be possible to inject the area through ports in existing cracks. Care should be taken to avoid lifting the slab by the viscosity and/or volume of the media injected as well as simply monitoring the extent of injection below the slab.

One prior theory to explain why the slab was cracking was heaving and swelling of the underlying and surrounding soils due to surface water infiltration. The soil report for the neighboring amphitheatre construction indicated that the soil is primarily sandy in the upper layers. This soil type would not exhibit swelling behavior due to water. There are problems, however due to the erosion effects of water runoff. The runoff by surface water at the northwest corner of the original house has caused erosion of the soil, resulting in settlement and cracking of the slab in that area. We recommend that all surface water runoff be evaluated and controlled.

Should you have any questions on this report or we can be of any further assistance; please do not hesitate to call. Thank you.

Signed Raymond S. Pugliesi

Copies to

APPENDIX E: Applied Materials and Engineering Testing and Investigation Report

The following report by Applied Materials and Engineering (AME) describes the testing carried out by AME to evaluate the causes of cracking at the ornamental floor and discusses the conditions observed.

October 26, 2004

Project Number: 104470C

Mr. Evan Kopelson
ARCHITECTURAL RESOURCES GROUP
Pier 9, The Embarcadero
San Francisco, CA 94111

Fax Transmittal: (415) 421-0127

Subject: Concrete Slab-on-grade Condition Assessment
Simon Rodia's Towers (Watts Towers), Watts, California

Dear Mr. Kopelson:

As requested, we have conducted an investigation of the concrete slab-on-grade construction at the above-captioned project. The investigation consisted of the following:

1) mapping existing cracks in the slab,
2) conducting ground-penetrating radar surveys,
3) soundings,
4) rebound number measurements,
5) sampling and testing the soil surrounding the structure.

The purpose of our testing and evaluation was to determine if there is reinforcing steel in the slab, and to evaluate the observable cracks in the slab.

SITE OBSERVATIONS

The concrete slab was placed around mortar-ornamental metal towers, known as Simon Rodia's Towers, and commonly referred to as the Watts Towers. The concrete appeared to have been placed in stages and various time intervals during the construction. The concrete slab sections were colored using pigments added to the concrete mixtures.

The concrete slab was placed in a triangular-shaped lot, with the north and south sides confined by mortar-ornamental walls. The west side of the slab partially surrounded the remnants of a residential foundation.

Nearly the entire slab contained intricately stamped and hand-tooled designs, and randomly placed hand-tooled joints. The placement of the joints appeared to be a function of the artistic design rather than for crack control purposes. The colored slab sections were typically separated by cold joints, indicating the sections were placed at different times.

Cracking in the slab sections was random. The cracking ranged from very fine (hairline) craze cracking with approximately 1″ to 2″ spacing between cracks, slightly larger spider cracking and spacing up to approximately 3″, and transverse cracks at random intervals with crack widths ranging from hairline up to 0.050″. In places, particularly near the west side, larger transverse cracks had been repaired with what appeared to be portland cement mortar. The original width of repaired cracks was not determined.

Photos 1 through 9 show some of the typical patterns, colored sections, crack patterns and repairs observed.

TEST METHODS & RESULTS

1. Crack Mapping Survey

The entire slab area was examined for the presence of cracking. If the crack was observable by the un-aided eye it was recorded onto enlarged photocopies of a hand-drawn site plan supplied by Architectural Resources Group. Cracks wider than 0.02″ were highlighted in red. Craze and spider cracks were not drawn on the plans due their small size, but were identified on the plans were their presence was obvious. These areas are identified as "craze", "crazing" or "spider cracking."

Figure 1 is a plan drawing showing the entire area surveyed. The area was separated into 6 sections identified as Sections A through F and are presented in Figures 2 through 7. A separate drawing was made for the gazebo, which is presented in Figure 8.

Most of the cracking appeared to be due to early age drying shrinkage, which produced a random crack pattern. Cracks also developed in hand-tooled joints and cold joints between separately placed colored sections.

Vertical offsets along cracks were limited to two locations. There was an approximate ½″ offset at a cold joint northwest of the West Tower between the yellow colored and green colored sections in the slab (see Figure 4). The northwesterly section (green colored) had displaced downward relative to the southeasterly (yellow color) section. The other area of vertical offset occurred directly in front of the north gate where a 1⅛″ offset developed at a crack in the green color section and extended to the cold joint between the green and natural gray colored section (see Figure 7). The northernmost slab sections were displaced downward relative to the southernmost sections.

2. Reinforcement Survey

The surface of the slab was surveyed using a Fisher M-100 reinforcing locator, which is capable of locating ½″ diameter reinforcing steel bar at a depth of approximately 3½″. In addition, Ground Penetrating Radar (GPR) was used to survey the slab. The GPR equipment, which utilizes a 1500 MHz antenna, has the potential to detect reinforcing to a depth of 12″.

During our non-destructive survey of the slab, no reinforcing steel could be detected. Based on this data, we have concluded that there is probably no reinforcing steel in the slab, nor are the individual slab sections tied to one another with dowels.

3. Sounding Survey

A "chain-drag" survey was conducted over the entire surface of the slab to detect delaminated surfaces and unsupported slab conditions. The chain-drag was conducted in general accordance with ASTM D4580, "Detecting declinations in concrete decks by sounding."

Isolated areas of the slab produced hollow sounds during the chain-drag, indicating delaminations and/or unsupported slab. These areas were typically small and isolated in the eastern portion of the slab (east of the Center Tower) and typically large and nearly continuous in the western portion of the slab (west of the Center Tower). Approximately ⅔ of the gazebo slab produced hollow sounding indications.

The areas of hollow sounding indications are shown in Figures 2 through 8.

4. Rebound Number

A survey using a spring-driven steel hammer (Schmidt hammer) was performed following procedures outlined in ASTM C805, "*Standard Test Method for Rebound Number of Hardened Concrete*." The test is used to assess the in-place uniformity of the concrete, to delineate concrete areas in a structure that may be of poor quality or deteriorated, and to estimate the in-place concrete compressive strength.

Because the spring driven hammer tended to dimple the slab surface and conditioning the surface with a grinding stone was not allowed, the tests were limited to four locations. Tests were conducted on the east end (east of the "ship"), on the north and south sides of the Center Tower, and on the northwest corner near the north gate.

The rebound numbers were consistent at each location and similar for each location. The average rebound number was 42, which indicated a relatively strong concrete, based on the calibration scale for the Schmidt hammer. It should be noted that no concrete sample was removed from the slab and therefore no direct calibration of the rebound hammer to the actual compressive strength was made. Table I presents the rebound hammer test data taken on the slab.

5. Soil Testing

A soil sample was removed from the north side of the slab (directly due north of the Center Tower) for laboratory testing (photo 10). The sample was considered to be representative of the grade the concrete slab was placed on. The purpose of the testing was to determine if the soil is expansive and could have contributed to the cracking in the slab.

The soil was tested in accordance with ASTM D4318, "*Standard Test Method for Liquid Limit, Plastic Limit and Plasticity Index of Soils*." The tests indicate the soil is mainly composed of dark brown silty sand. Sand is non-plastic and the soil is considered to be non-expansive. The moisture content of the soil at the time of the sampling was 5.5%.

DISCUSSION AND CONCLUSIONS

The following information was obtained:

A. Reinforcing Steel

1. No steel reinforcement was located in the slab. The slab sections were not tied together with dowels.

B. Evaluation of Cracking

1. Cracking was random, ranging in width from hairline to 0.05″ for non-repaired cracks.

2. Noticeable offsets between slab sections occurred in two locations. The offsets ranged from ½″ near the Center Tower to 1⅛″ near the north gate. The northernmost slab section moved down in relation to the southernmost section in both locations.

3. Areas of delaminations and/or un-supported slab where common. The largest and most continuous un-supported slab sections occurred in the western portion of the slab.

4. Nearly ⅔ of the gazebo slab was un-supported and/or delaminated.

5. The slab appeared to be uniform in rebound strength in the four locations tested.

6. The soil supporting the slab is not expansive. The soil is composed mainly of dark brown silty sand (non-plastic).

7. The most likely cause of the cracking was early drying shrinkage.

Please call if any questions arise.

Sincerely,

APPLIED MATERIALS & ENGINEERING, INC.

Jon Asselanis
Materials Scientist/Petrographer

Armen Tajirian, Ph.D., P.E.
Principal

TABLE I

REBOUND NUMBER – SCHIMIDT HAMMER READINGS

Simon Rodia's Towers (Watts Towers)

AME Project No. 104470C

Location	Location Description	Reading Average	Readings									
			1	2	3	4	5	6	7	8	9	10
1	East of "Ship"	41	43	39	39	42	45	43	38	42	38	41
2	North of "Center Tower"	44	46	42	44	43	40	45	45	44	44	42
3	South of "Center Tower"	43	43	39	44	46	45	42	41	39	42	45
4	Northwest corner near "North Gate"	40	40	39	39	40	42	40	42	41	39	42
Average		42										
Standard Deviation		1.43										
Coefficient of Variation, %		3.4										

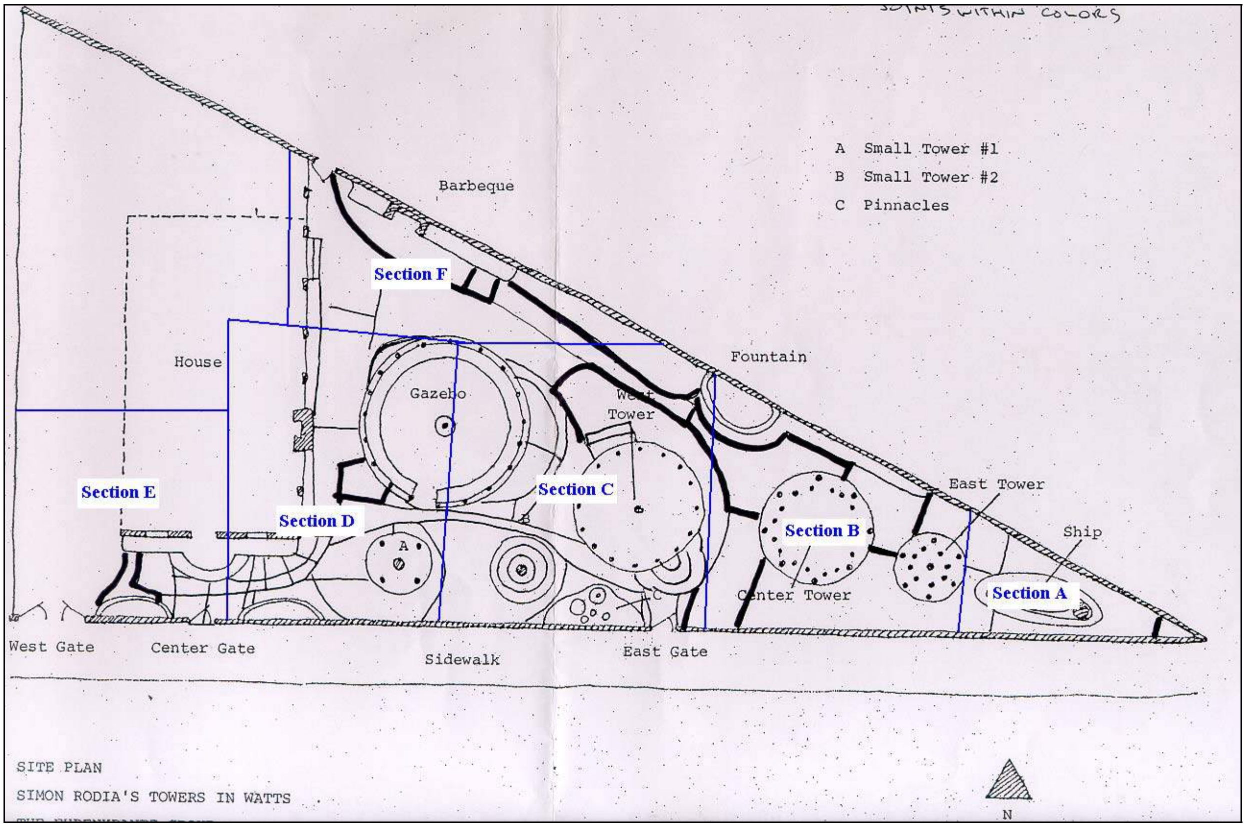

Figure 1. Plan drawing of Rodia's Towers showing detail sections.

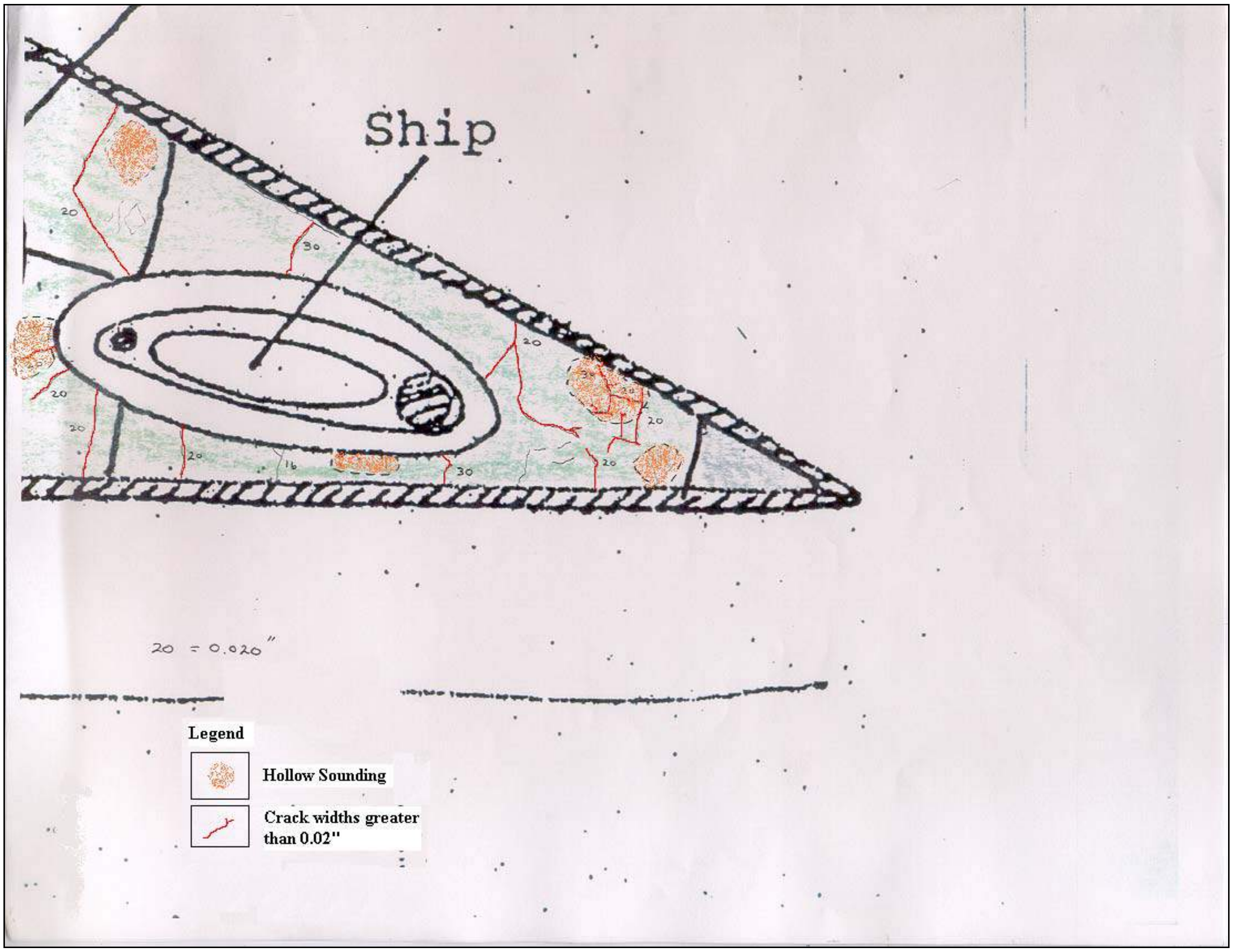

Figure 2. Section A -- East end of property (Ship)

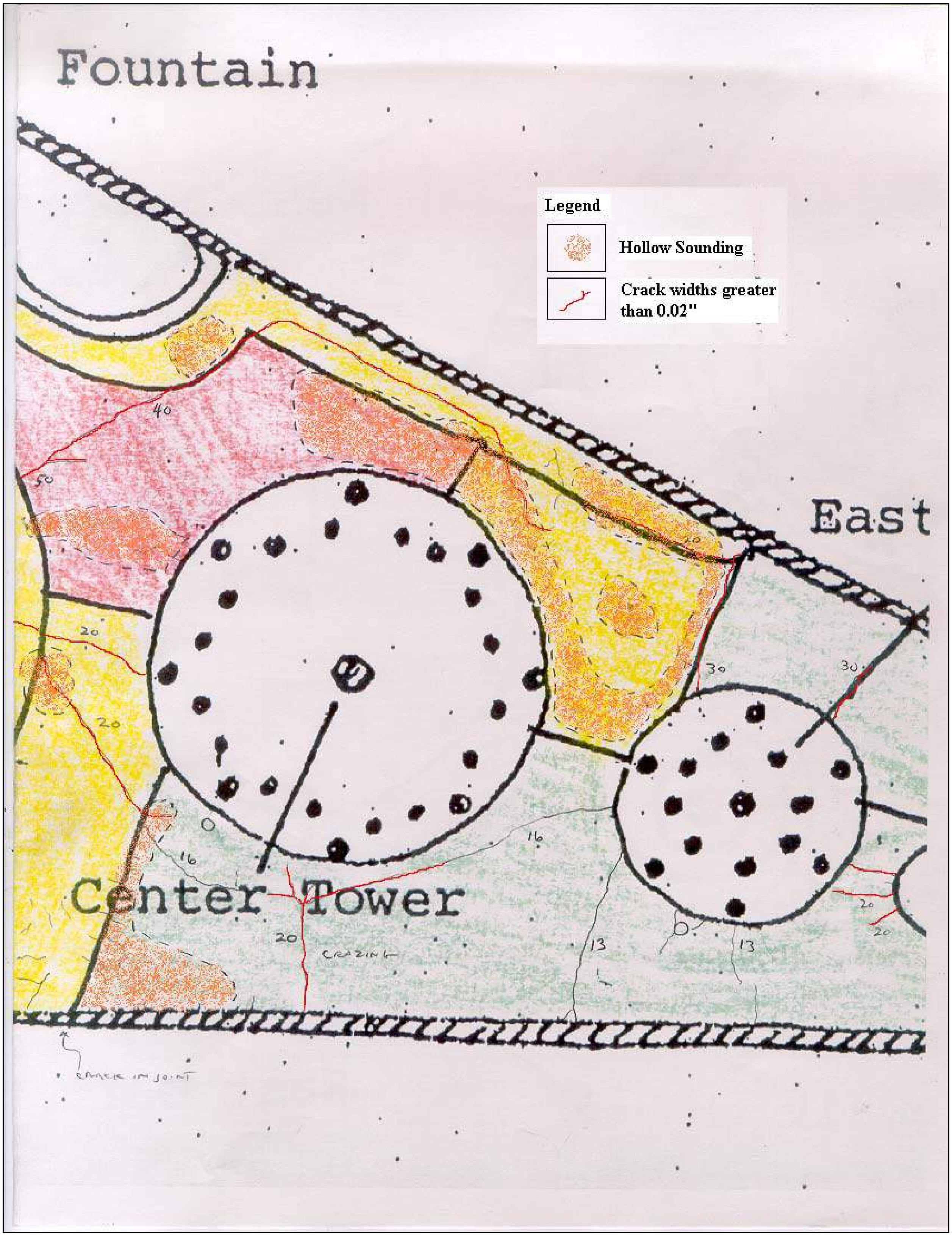

Figure 3. Section B --Westerly center section of property (Center and East Towers)

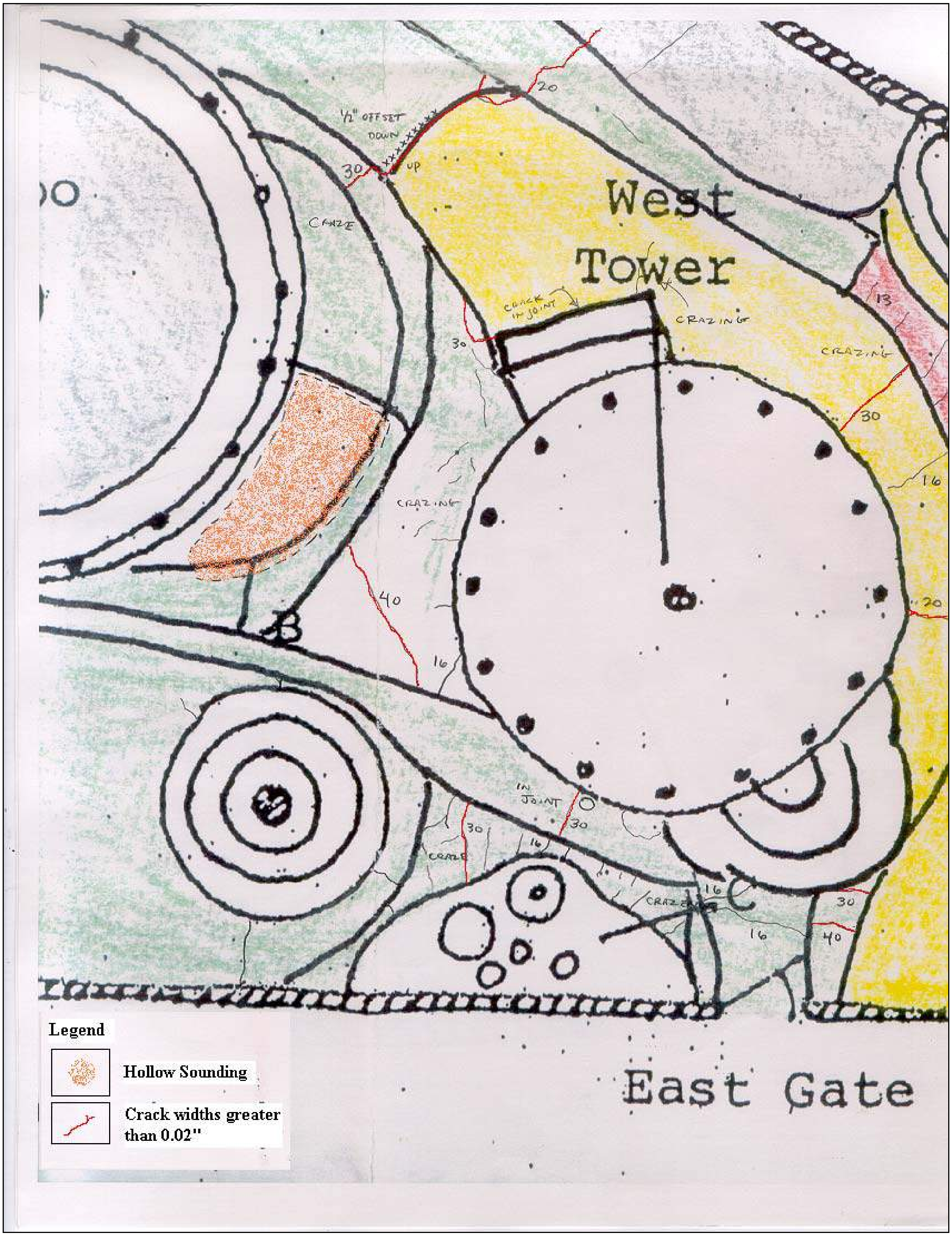

Figure 4. Section C -- Westerly center section (West Tower and East Gate)

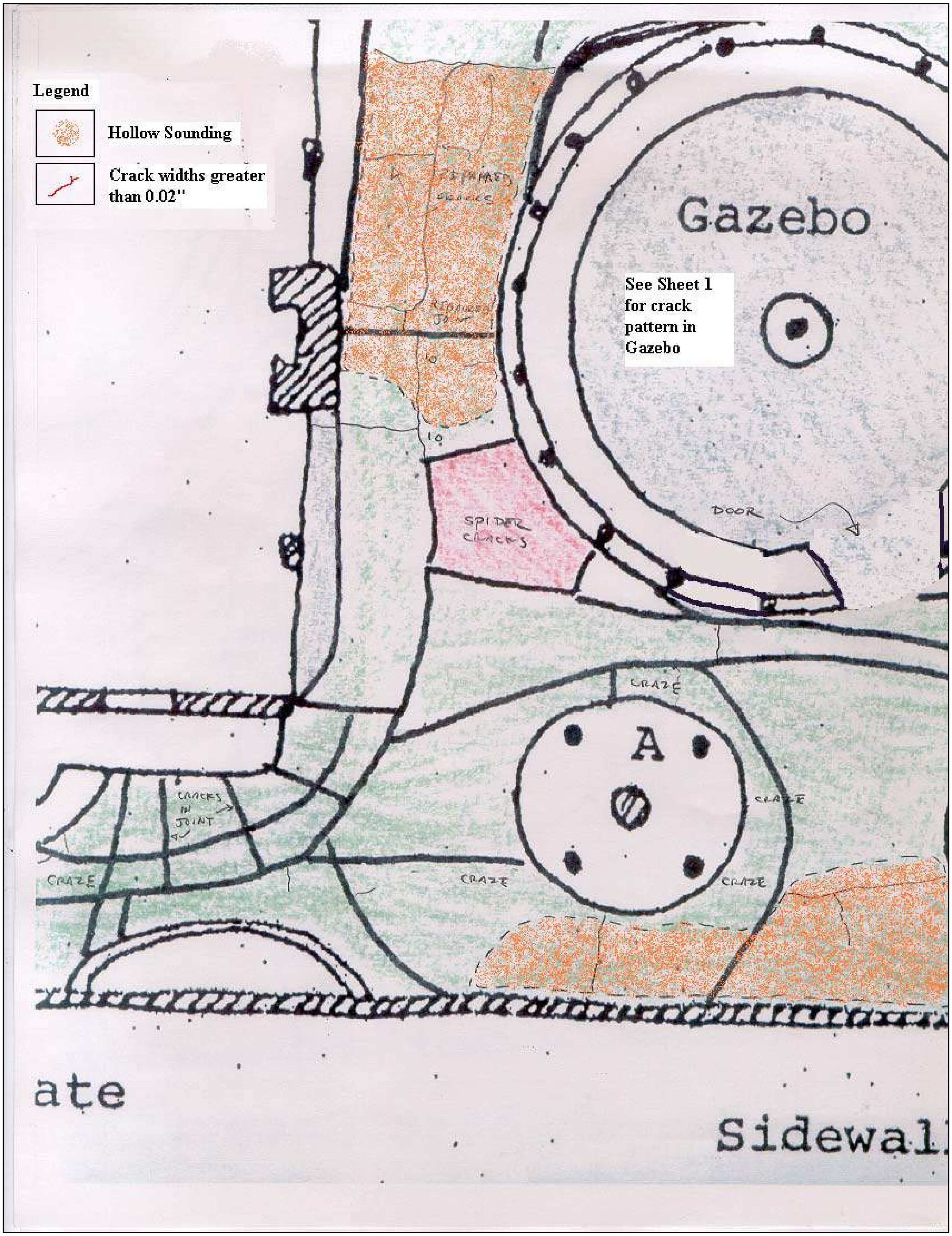

Figure 5. Section D -- Westerly center section (Gazebo and Tower A)

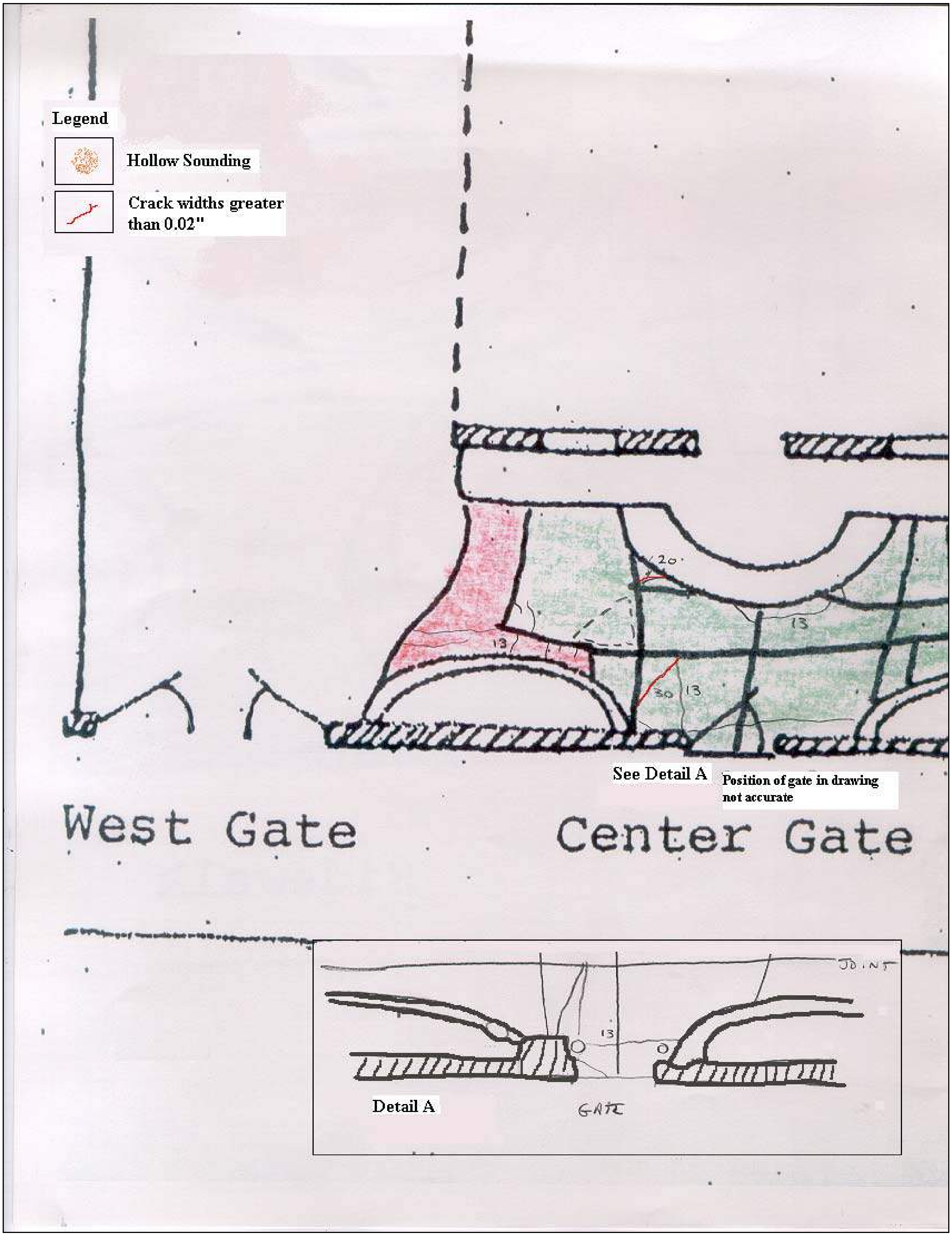

Figure 6. Section E -- Southwest corner section (Center Gate)

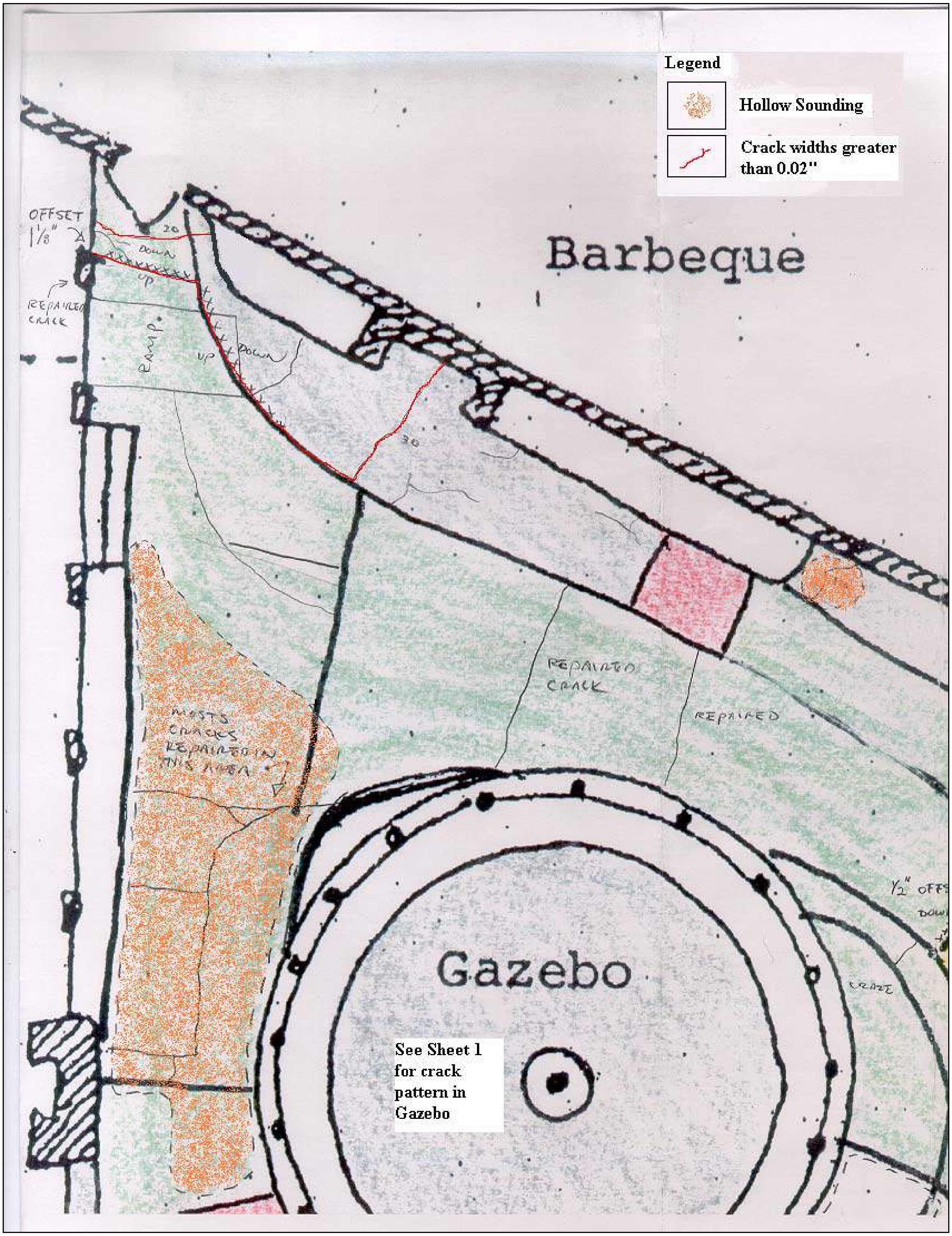

Figure 7. Section F -- Northwest corner section (North of Gazebo)

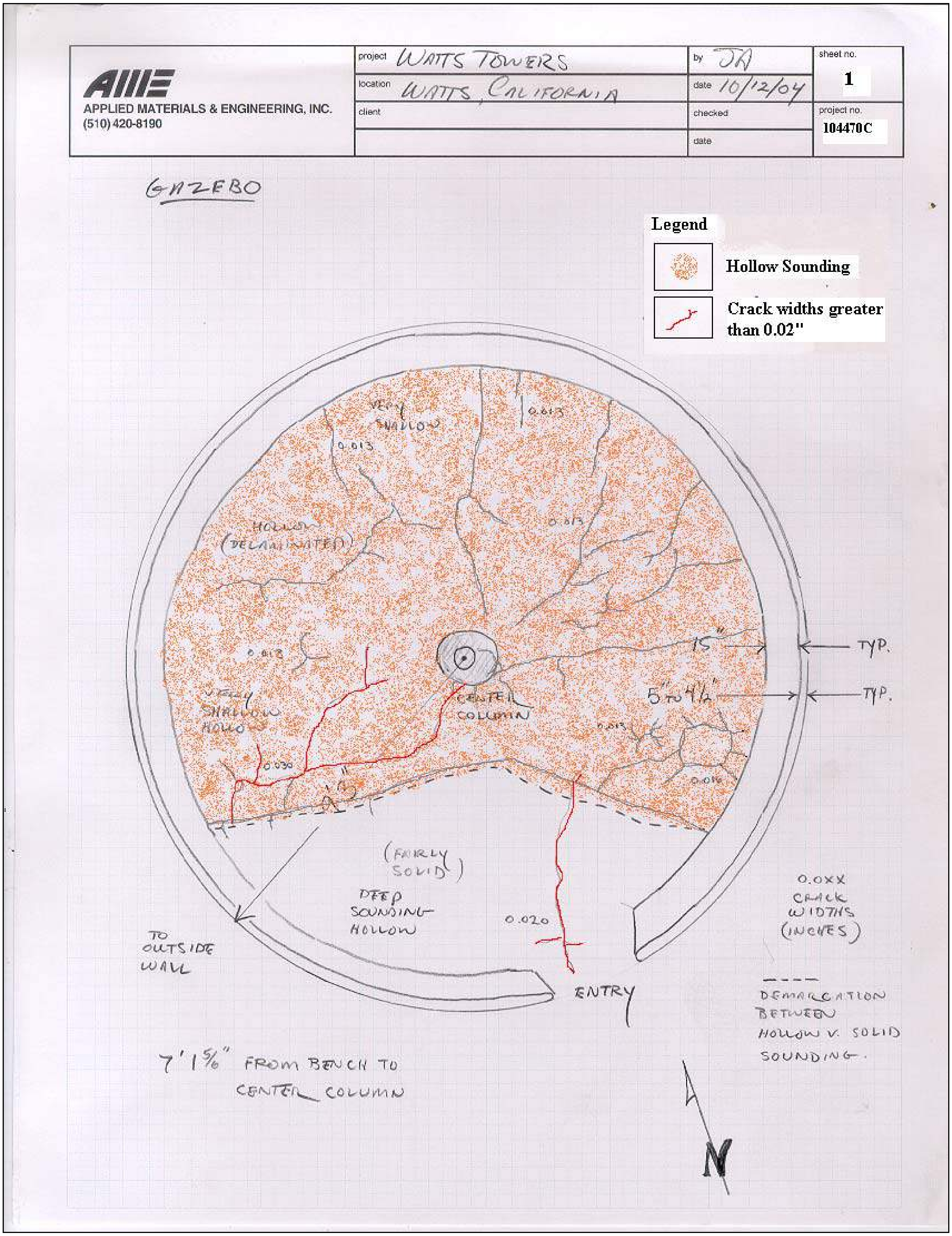

Figure 8. Sheet 1 from field notes. Gazebo crack pattern and area of hollow sounding.

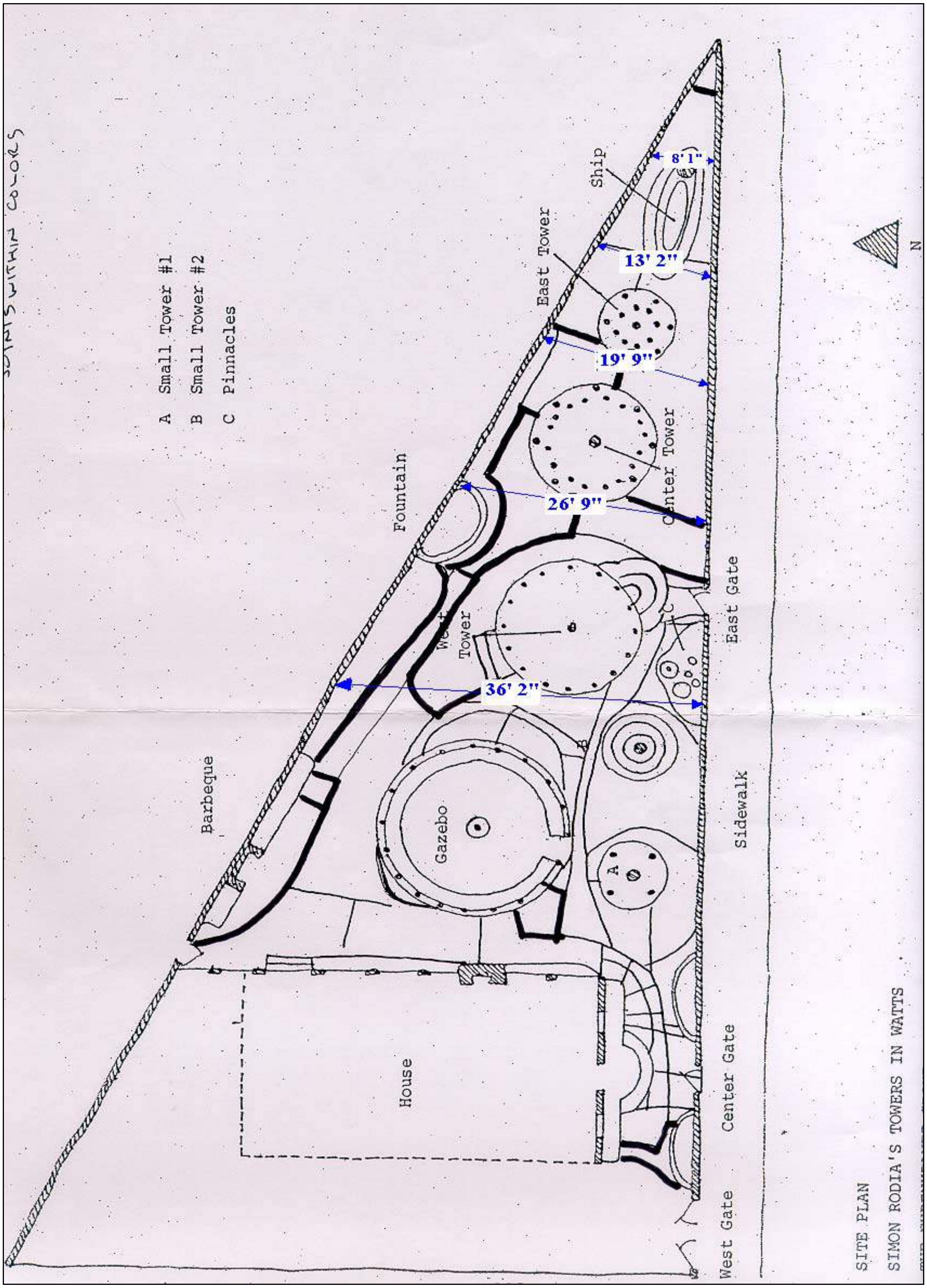

Figure 9. Distance measurements are various locations across property.

Photo 1. South side of slab near gazebo. The stamp patterns, joint locations and coloring of sections are typical of the entire slab area.

Photo 2. Stamped patterns in walkway.

Photo 3. Crack development within sections. The cracks typically occurred perpendicular to the longest axis of the placement.

Photo 4. Crack pattern in Gazebo. The area in the foreground of photo had the least amount of cracks and had solid sounding indications. The area in the background (behind pedestal) had a large number of cracks and had hollow sounding indications.

Photo 5. Slight uplift between colored sections just northwest of Center Tower (arrow).

Photo 6. Cracking between color sections in southern portion of slab.

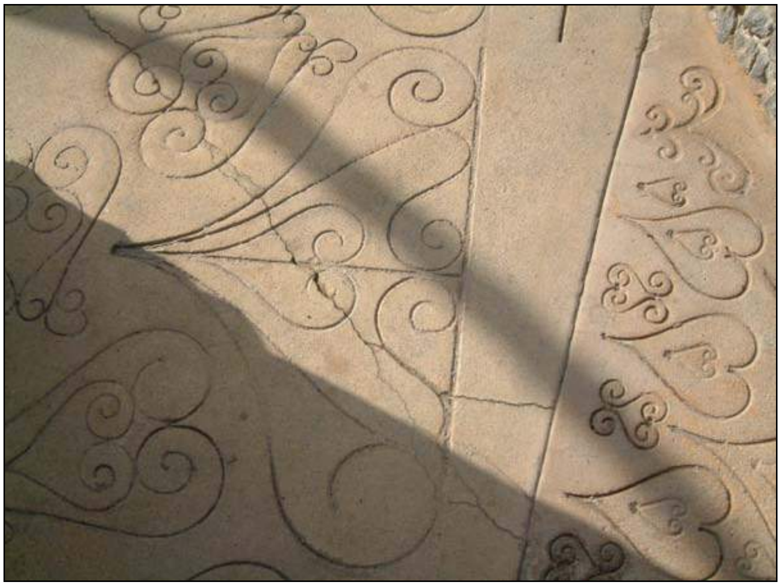

Photo 7. Cracking within section

Photo 8. Crack bisecting section and crossing joint (arrow).

Photo 9. Repaired cracks in west portion of slab just west of West Tower.

Photo 10. Soil sampling location on north side of property just outside wall.