Rehabilitation and Cathodic Protection of the Pohnpei Japanese Agriculture Station

Sub-Themes: Unloved Heritage, Re-Thinking Colonial Heritage, and War in the Pacific

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Abstract:

The Pohnpei Japanese Agriculture Station was one of five buildings still standing after the World War II (WWII) bombing of the Japanese colonial capital city of Kolonia in the Caroline Islands. The 1926 Art-Deco stepped-pyramid reinforced concrete building was designed by Yamashita Yasaburô, the premier Japanese architect in the Pacific prior to the war.

North Façade of the Japanese Agriculture Station Building, 1999. Photo credit: David W. Look

Although the building was used intensively after the war by the Trust Territory of the Pacific Department of Agriculture, it was been abandoned since the 1970s and is in poor condition. The building is located between two roads in the middle of a triangular plot, known as the Pohnpei Botanical Gardens. In general, WWII was a period of horrible memories for most Micronesians and their Japanese Heritage has not been appreciated. Some in Pohnpei want to demolish this monument and building a modern museum but are beginning to consider other options.

Based on the possibility of reusing the building for the Pohnpei Museum, the Pohnpei Historic Preservation Office and the U.S. National Park Service (NPS) obtained a $40,000 grant from the U.S. National Center for Preservation Technology and Training (NCPTT) to provide assistance in the conservation of endangered cultural landscapes and concrete. NPS brought together a faculty of experts to visit the site and provide technical assistance, training and recommendations.

Historically, reinforced concrete was promoted as a maintenance-free material and few modern architect and engineers have any knowledge or understanding of its deterioration or conservation. The Oregon Department of Transportation has pioneered the rehabilitation and retrofit of its historic coastal concrete bridges using cathodic protection. Once the deteriorated concrete is removed and area repaired with compatible concrete, existing reinforcing bars are located by non-destructive testing, anodes and cathodes are connected to the reinforced bars by drilling, and anodes and cathodes are hooked up to a passive (large block of zinc or zinc coating) or active source of electricity. Since the high cost of fuel and typhoons result in months of no or

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intermittent electricity, solar collectors are being considered for providing power to the museum. Although cathodic protection is being used in Europe on a few stone buildings to prevent future corrosion of fasteners, this technology could be used around the world to rehabilitate reinforced-concrete structures which are now becoming historic, but deteriorating because of a lack of maintenance.

Paper

Introduction

In 2002 Youser Anson, the Pohnpei State Historic Preservation Officer, and Tevita Salato, the Director of the Pohnpei Visitors Bureau requested NPS provide technical assistance and training for the Japanese Agriculture Station. Working with Messrs. Anson and Salato, David W. Look, FAIA, FAPT, Deputy Lead for Cultural Resources and Chief of the NPS Micronesia Programs in the Pacific West Region (PWR), developed a grant application and submitted it to National Park Service (NPS) National Center for Preservation Technology and Training (NCPTT) in Natchitoches, Louisiana. In 2005 the grant application was approved and a $40,000 grant was awarded to the PWR. The technical assistance allowed an opportunity to incorporate training and student exercised into the investigation by the assembled team of experts from various disciplines. The five-day training class was attended by 24 students and covered the two identified major concerns: (1) endangered cultural landscape and (2) concrete deterioration and preservation. This paper will only cover concrete conservation, which consisted of two-and-a-half days of class room presentation, demonstrations, and exercises.

The training class was held in the conference room of the Secretariat of the Pacific Community (SPC) in the Pohnpei Botanical Garden. Youser Anson, Pohnpei State Historic Preservation Officer co-chaired the training and technical assistance and U.S. Ambassador Suzanne Hale welcomed the students and faculty.

During the cultural landscape module of the training, Prof. Dirk Spennemann, Charles Sturt University, and Wakako Higuchi, University of Guam, presented their German and Japan Colonial agricultural research. These presentations on the history and development of agriculture and the development of the station was not repeated in the module on concrete conservation because the same students attended both modules. A brief overview of the history and development during Japanese and Trust Territory periods will be given in conference presentation but not covered in detail in this paper.

Module Two of the training on concrete conservation started on Wednesday afternoon. Mr. Look gave an overview of Module Two and explained the learning objectives. He gave the first presentation which was a brief history of concrete from Roman times through the late 19th Century when iron and steel reinforcing was added to increase the concrete capacity of the concrete construction for tension and shear and into the early part of the 20th Century. During the Middles Ages the construction of concrete was kept alive in Spain and North Africa and later introduced to the New World by Spain. This included the Merizo Combento (1856) on Guam. He explained why there is great variation in concrete from building to building because of all of the various factors: different types and manufacturers of cement, various types and sources of sand and aggregate, sources of water, and consistency of mixes and workmanship. He introduced preservation considerations that must be taken into consideration when applying the four recommended treatment options: restoration, preservation, rehabilitation, and reconstruction. Mr. Look explained how the five basic principles of (1) research and documentation, (2) authenticity and integrity, (3) compatibility (both visual and physical), (4) minimal intervention, and (5) reversibility are applied in the Secretary of the Interior's *Standards for Preservation Projects.*

Prof. Emeritus Donald Peting, retired head of the Historic Preservation Program at the University of Oregon followed up with a presentation on documentation of the building. He introduced the students to the Historic American Building Survey (HABS)/Historic American Engineering Record (HAER) programs that document historic buildings, structures and sites with written histories, large format blackand-white photographs, and archival drawings. He explained how to take measurements at waist height in a consistent and methodical way to make sure that all dimensions add up. Prof. Peting had a student put them into AutoCAD. The students' detailed measurements and drawings will be used after the class to have the University of Oregon student updates the drawings. At the end of the day there was ample time for questions and discussion.

Since no original drawings of the building have been located and there was no knowledge of the buildings foundation, Prof. Spennemann volunteered to obtain a permit from the Pohnpei HPO to excavate a small section along the south wall toward the west end. He documented what he found and left a draft report for the Pohnpei HPO. He also explained his findings to the other instructors and students. The depth of the foundation, the extent of the area dug out for construction of the foundation, size and nature of the foundation, and the original grade level were learned. This was a bonus at added no additional cost to the training and technical assistance.

Thursday morning Prof. Peting and Mr. Look gave the students a tour of the Japanese Agriculture Station building. The students were divided into seven three-person measuring teams. One for each of the following areas: first floor east, first floor west, second floor east, second floor west, third floor east, third floor west, and roof and tower area. Prof. Peting measures the stair himself on Saturday after the class ended. Each team was asked to do a simple sketch of its room or area and then annotate the sketch with the measurements.

Thursday afternoon consisted of four presentations. Paul Gaudette, P.E., Wiss, Janney, Elstner Associates, Inc., introduced the students to concrete deterioration from all of the causes and contributing causes, especially the corrosion of iron and steel reinforcing bars. Frank Nelson, P.E., Oregon Department of Transportation, explained in great scientific detail why and how metals corrode and how the great expansion of rust on the reinforcing bars in concrete causes the surface of the concrete to crack and spall. Mr. Gaudette concluded the day with three sessions: (1) condition survey and testing of concrete, (2) repair materials, and (3) repairing and matching techniques. These methods focused on non-destructive testing, especially low-tech tests such as hammer tapping and dragging a chain over the surface to detect the sound of hollow and/or delaminated areas.

On Friday morning, Mr. Look presented the Secretary of the Interior's *Standards for Preservation Projects* and reviewed the four recommended treatments: preservation, restoration, rehabilitation, and reconstruction. He explained how even in a rehabilitation project, some features may be preserved and some may be restored or reconstructed. Since rehabilitation is the most flexible treatment and allows for some sensible and compatible additions and introductions of new systems and features, when necessary, provided that the salient historic spaces and features are retained and not obscured, he presented the *Rehabilitation Standards* and related each of the standards to the five basic principles in general and to the Japanese Agriculture Building in particular. Mr. Look concluded his presentation with a discussion of the Section 106 process for U.S. Federal funded projects and the Pohnpei compliance process. By meeting early with the HPO, a project can benefit from the expertise of the HPOs staff and by complying with the Secretary Standards, there is no adverse effect to be mitigated.

Mr. Gaudette demonstrated on-site investigation and field testing. In the Japanese Agriculture Station building he set up a work table (two saw horses and a piece of ¾-inch plywood with various samples and test that he demonstrated and the students could try. He also engaged the students in taking a sample without the availability of a core bit. Students mapped cracks on their drawings and areas of deterioration based on the sound tapping with hammers.

Mr. Gaudette discussed the analysis, evaluation, and development of treatment plan and how to evaluate alternatives. After the break Mr. Gaudette gave his presentation on concrete cleaning and coating removal techniques which stop short of doing any damage to the resource. Mr. Nelson presented concrete protection including cathodic protection and other options that have been used by the Oregon Department of Transportation (ODT) on it coastal highway bridges for over 15 years. He explained the advantages and disadvantages of each and how they might be applied to the Japanese Agriculture Station building. At the 2005 National Preservation Conference in Portland, Oregon, ODT received an award for its preservation efforts on its historic bridges, especially its coastal bridges where cathodic protection has been used. The wrap-up session included questions and discussion and collection of evaluation sheets and student recommendations.

Concrete Deterioration[2]

The exterior of the Japanese Agriculture Station Building is in better condition that the interior. The interior of the building is relatively intact but in poor condition because of water infiltration that has drained down through the building from the roof and through the windows and doors which are missing and therefore do not provided any protection from the weather. However, the building is well built and shows fine workmanship and good quality of materials. The building was built during the civilian Japanese Administration when there were no shortages of materials or experienced construction personnel and the quality of the concrete work is much better than the hastily constructed concrete work done by the Japanese military late in World War II when there was a scarcity of materials.

From preliminary observations, it appears that that there may have been lime in the concrete. This is based on the presence of pieces of shell in the concrete. Although shells may have been used as part of the aggregate, it is also possible that these are unburnt pieces of shells that were burnt to make lime for construction.

General Conditions

Concrete deterioration on the interior of the building is related to corrosion of embedded steel, and as a result, deterioration of the concrete itself. Corrosion of steel occurred where embedded reinforcing steel is not protected by the concrete's normal alkaline environment, (which may be due to carbonation and the presence of sufficient chloride ion), and the steel is exposed to water or high moisture levels. The concrete deterioration at the interior of the Agricultural Station Building was primarily caused by corrosion of embedded steel due to carbonation of the concrete and moisture penetration. On-site pH testing revealed that the concrete was carbonated to a depth beyond the level of the embedded reinforcing steel and as a result the concrete no longer was alkaline enough to protect reinforcing steel. This testing consists of application of phenolphthalein to a freshly-fractured concrete surface. The surface of the concrete turns pink where the pH level is greater than 10, which indicates an alkaline environment sufficient to provide protection to the embedded reinforcing steel.

Columns

Interior columns exhibited significant corrosion of embedded reinforcing steel, which has resulted in delamination and spalling of concrete cover from the interior surfaces of the column. The majority of concrete cover over interior columns has spalled to level of embedded reinforcing steel. The exterior faces of the columns, at the exterior of the building, had some corrosion of the reinforcing steel, and on the face of the building, had spalled significant sections of concrete. These columns are visible at the outside corners of the bays on the building facades. Reinforcing steel was severely corroded with significant loss of cross-sectional area.

Girders and Beams

Virtually all interior girders and beams exhibited significant deterioration of concrete due to corrosion of embedded reinforcing steel. The corrosion has resulted in cracking, delamination, and spalling of all concrete cover from the bottom and side surfaces of the girders and beams. The majority of concrete cover over interior girders and beams has spalled to level of embedded reinforcing steel. Reinforcing steel was severely corroded with significant loss of cross-sectional area.

In several areas of the building repair work has been performed on the bottom of concrete beams and girders. The repair consisted of application of a cement mortar over the spalled area or installation of a wire mesh then application of the mortar. Generally, these were not effective because it does not appear that the old reinforcing bars were adequately cleaned. In addition, the roofs continued to leak providing moisture that made possible new corrosion.

[2] This section was written by Paul Gaudette.

Floors

Floor slabs are in fair condition. The top surface of the floor slabs are covered with a thin bonded architectural mortar topping. At some locations, in particular the third floor slab (second floor ceiling) in the south room, severe corrosion of reinforcing steel was observed as well as extensive spalling of concrete. Organic growth was most severe at the second and third floor ceilings and walls.

Interior Facing Mortars

The colored concrete facing mortar was found in two colors: red and green. The facing mortar was used on the top surface of the floors, stairs and landings, on the wainscot and baseboard at the base of the walls, and at window sills.

First Floor

In general, the first floor is in better condition that the floors above because of the deterioration from the leaking roofs and from the driving rain coming through window and door openings. All of this water drains down through the building and soaks into the concrete.

Second Floor

In general the second floor is in poorer condition than the first floor, especially in the area under the third floor east and west terraces.

Third Floor

Because of the leaking roofs over the original third floor and the two cover terraces, the third floor had much deterioration.

Fourth Floor and Roof

The fourth floor terrace also appears to have been covered with a concrete topping. It is not known if there was originally roofing on the fourth floor terrace. It is also not know if that roofing was removed, or if the topping added later was installed onto the concrete slab, original roofing, or new roofing.

Scuppers were located at the southeast and southwest corners of the terrace, [3]which provided drainage for the terrace when it was exposed to weather. The scuppers were covered by the addition of the topping slab and there is no observed method for water to drain off the terrace. Water was observed leaking out of the southwest scupper drainpipe after a rain storm.

The existing parapet appears to be intact but is quite low due to the addition of the topping slab. Random cracking was observed throughout the inside face of the parapet wall.

For lack of a water tight roof and maintenance, the concrete deterioration spread down through the building.

Rehabilitation and Cathodic Protection

The following definitions are given for readers who are not familiar with cathodic protection.

Cathode: The electrode at which chemical reduction occurs.

Cathodic protection: A form of corrosion protection for reinforced concrete wherein a sacrificial metal is caused to corrode in preference to the reinforcement, thereby protecting the reinforcement from corrosion.

Cathodic protection, impressed current: A protection system that uses an external power supply to force a small amount of electric current through the reinforcing steel to counteract the

[3] This section was written by Frank Nelson and David Look.

flow of current caused by the corrosion process; a metal, such as platinum that corrodes at a very slow rate, is typically provided as an anode.

Cathodic protection, sacrificial: Protection system that does not require an external power supply; a metal, such as zinc that is less noble or more prone to corrosion than steel, corrodes in place of the reinforcing steel thus protecting the structure.

Uses of the Rehabilitated Building

Two uses have been proposed for the Japanese Agriculture Station Building: (1) Visitor Center and Museum and (2) offices.

In 2002 Youser Anson, Pohnpei Historic Preservation Officer, and Tevita Salato, Director of the Pohnpei Visitors Bureau, requested assistance of the National Park Service to rehabilitate the Japanese Agriculture Station Building. The proposed use at that time was visitor center, book store, and offices on the first floor, museum on the history and prehistory of Pohnpei on the second floor, and museum on the history of research on agriculture and horticulture on the third floor. This proposed use appears to be an appropriate and compatible use for the building, similar to the use of the Old Japanese Hospital on Saipan, which has been rehabilitated at the Saipan Museum, and would probably need **Standard 1.** Both building were designed by Yamashita Yasaburô, Architect of the South Seas Bureau.

The difference between these two building is that the Old Japanese Hospital is one story and the Japanese Agriculture Station Building is three-stories with a fourth story tower. The accommodation for handicap accessibility of the Old Japanese Hospital for the Saipan Museum was not difficult because it is all on one level. The Japanese Agriculture Station Building has only one stairs from floor to floor. These stairs are narrower above the first floor and have winders (pie-shaped step treads), which are not allowed by modern codes. Normally, accessibility of a multi-story building is by providing an elevator with access to each floor level. To add an elevator within the building would result in a lost of space and a lost of historic fabric and integrity. The building has previously had additions. An addition on the back of the building for a second set of stairs that meet current codes and an elevator is one alternative that might be studied. This addition might also be a good location for accessible restroom(s) or these facilities could be another structure that could be used by everyone visiting the Pohnpei Botanical Gardens whether or not he/she is visiting the Japanese Agriculture Station Building.

The problem with an elevator is that the nearest elevator mechanic is two hours away by air. Since flights are on alternating days, it might take days for assistance to arrive. If the elevator malfunctioned or there is a power failure, people could be trapped in a hot elevator for hours or days and could cause a life-threatening situation. There are new pneumatic elevators that have been introduced that automatically return by gravity to the first floor and open. This would eliminate the concern of being trapped in a hot elevator. At present pneumatic elevators are only used for residential use because there are no code provisions for pneumatic elevators. Also pneumatic elevators are currently more expensive than hydraulic elevators, but there is no shaft, thus there is some savings in construction. These and other options for vertical circulation would need to be studied. By the time the Japanese Agriculture Station Building is under construction, codes may include pneumatic elevators, commercial pneumatic elevators may be available, and the cost of pneumatic elevators may be comparable with hydraulic elevators.

It has also been suggested that the Visitor Center or Contact Point for both the Pohnpei Botanical Garden and Pohnpei Museum be located in another building and the entire first floor of the Japanese Agriculture Station Building be devoted to museum use and possibly the second floor. The third floor could be used for offices.

One of the attributes (assets) of the third and fourth floors of the Japanese Agriculture Building is its height and 360 degree panoramic view of the Pohnpei Botanical Garden, Kolonia, the mountains, Sokehs Ridge, and the Pacific Ocean. Allowing access to the roof and any open terrace is a safety concern and would have to be carefully studied and planned. If passive cathodic protection is used, the roof might be a secure area to install a large block of zinc and/or solar collectors to power the cathodic protection and to provide power for the building. Access, safety, and security must be studied in the Historic Structures Report for the Japanese Agriculture Station.

There may be other uses. For each potential use, a decision will be made whether to keep or demolish the additions on the third floor terraces both east and west. Are these spaces needed to accommodate the proposed use and future growth? Can these enclosed terrace areas be use for secure viewing of the Pohnpei Botanical Garden? Other potential uses and these questions will also be considered during the research of the Historic Structures Report.

Recommendations for Concrete Preservation[4]

As substantial investment will be made in repairing, restoring or rehabilitating the Japanese Agricultural Station Building, it would be prudent to consider implementing means to preserve the concrete to mitigate and eliminate the need for significant further restoration in the future.

- For exterior concrete, sealers and concrete stains offer protection up to a decade at very minimal cost. Reapplication periodically is a necessary maintenance effort but not a great expense.
- Sealing interior concrete surfaces, in particular for exterior walls and ceiling slabs, is not recommended as this tends to trap moisture in the concrete, and will accelerate rather than slow down deterioration. Sealing of floor surfaces (tops of slabs) is recommended. The original construction used a thin mortar for this purpose, much of which is still functioning.

The insides of the walls and the underside of the floor slabs would be candidates for cathodic protection. This process involves providing a metal which will corrode at a faster rate than steel, an anode, which is easier to replace than the reinforcing steel. This, in effect halts the corrosion of the reinforcing steel, which is a primary cause of the damage to the concrete and presents a significant safety concern as the steel deteriorates. One method of providing cathodic protection is to thermal spray a thin layer of zinc on the walls and ceiling with periodic connections to the reinforcing steel. This leaves the surface looking like concrete and it can be painted for color match to the original concrete. A second method is to make thin grooves in the concrete every few feet and embed a special wire anode connected to reinforcing steel behind it. A third method uses a thermal sprayed zinc coating but to connect it to three small direct current power supplies (one for each of the main floors) that electrically move oxygen away from the steel and towards the zinc. The total power consumed would be less than a 60 watt incandescent light bulb. This approach offers the most protection but does require that someone check the power supplies once a month and after storms or power outages. In all cases, the anode metal is consumed in approximately twenty years and would need to be replaced. But the concrete would not need to be repaired again.

The appearance of zinc on the exterior of building on the concrete surface would be metallic in nature and quite bright and garish when first applied. The tropical climate and biological growth on the surface, however, would in time dull the metallic appearance. The historic concrete bridges along the Oregon coast have dulled over the years and the appearance has been accepted as meeting the *Secretary of the Interior's Standards for Rehabilitation*. The dull, weathered appearance is slightly more bluish than the warmer historic concrete. Mr. Nelson has stated that if the cooler gray appearance is not acceptable, the surface can be painted a warmer gray without substantially altering the cathodic protection. He also stated that the zinc coating did not need to be on the exterior of the building. If used on the interior, the zinc could be coated with plaster and paint. Since the condition of the interior plaster is very poor where it still exists, removing the deteriorated plaster to install the wires and zinc would not destroy substantial amount of existing material. It may be possible to only apply the cathodic protection to the upper floors of the building where the original concrete is deteriorated and is in need of repair. If this is possible, more original material could be retained and seen on the first floor interior.

Repair Approach

[4] This section written by Paul Gaudette.

The conservation and effective repair of the building is dependent on an understanding of the nature of the material, the pathology of deterioration, and the available repair technology and craftsmen. The challenge of this project is to execute repair work that will perform well, match the appearance of the original existing materials, and require the least amount of ongoing maintenance. The following discussion summarizes the phases of the recommended concrete repair project, including the investigation, laboratory analysis of materials, development of the concrete repair mix, trial repairs, and repair program.

Repair Strategy

The goal of the project will be to repair the interior and exterior concrete and install new windows, doors, and roofing. The only way to reduce the rate of future deterioration of building elements is by reducing the rate of moisture infiltration through the walls and roofs. The primary objective of the repairs is to use materials and techniques that will be sympathetic to the existing walls, structural components, and perform well. Finally, the repair design needs to meet the installation tolerances used in the original construction.

In order to achieve these goals, the project can be organized in three phases: development of trial repair materials and procedures; performance of repair work at a trial area of the building; and performance of repair work on the rest of the building interior and exterior. Trial mixes and repair techniques must be evaluated to determine how to best match the original appearance and properties of the various materials while providing a durable repair. Implementation of repairs at trial areas will permit technical and aesthetic evaluation of the completed repairs and an assessment of the scope of work and the contractor's procedures. Information gathered in the trial repairs is utilized in refining requirements for the project.

Recommend the following multi-phase approach be utilized:

Phase 1 – Developing trial repair materials and procedures, involved determining repair materials; developing and testing trial mixes; developing repair procedures and repair techniques; performing finishing samples, using various techniques; selecting repair materials and finishing techniques to match existing concrete, stucco, mortar toppings and facings, precast concrete; selecting system to reduce the amount of moisture penetration into concrete.

Phase 2 – Performing repair work at trial areas of the building included using trial repair materials and techniques; evaluating the work, modifying procedures, and repeating trial repair work as needed; and modifying repair materials and techniques to adapt to actual as-built conditions.

Phase 3 – Performing repair work at remaining portions of the building included incorporating lessons learned in Phase 2.

Conclusion

The repair and cathodic protection of the Japanese Agriculture Station would be an excellent model project to show the use of cathodic protection of existing historic concrete buildings. The concrete deterioration would be repaired and prevented from reoccurring. The approach could save thousands of historic concrete building around the world.