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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

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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

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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

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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

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