Kariotis & Associates STRUCTURAL ENGINEERS

CONFIDENTIAL

REPORT OF THIRD PARTY REVIEW OF WATTS TOWERS

Scope of the review

The scope of this third party review is to review the history of structural repairs to the central tower using the total available data base. In addition, the scope includes a visual examination of the central tower by use of equipment that enables a close examination of the upper part of the central tower.

The scope also includes a report on the results of a structural assessment, a risk assessment of the historic fabric of the central tower and recommendations for possible modifications of restoration procedures and of current structural repair procedures. The recommendations will also comment on record keeping of the structural repairs to allow future assessments of the effectiveness of completed structural repairs.

Visual observations

The visual inspection of the central tower was made on July 9, 2003. The equipment allowed the observers to approach the within three feet of the outer surface of the tower. The repair work observed is that completed during the period when full height scaffolding was used for the post-Northridge (1994) repair.

This inspection did not find corrosion-caused damage to the mortar skin with one exception. A vertical crack in the mortar coating on an exterior column on the west elevation of the central tower was observed. The location was about six to eight feet below the top of the tower. The length and open width of the crack does not indicate that the expansion of the metal core due to corrosion is substantial. There was no evidence that mortar coating of the tower members has detached from the center tower.

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This opinion is based on the premise that cracking of the mortar coating that is aligned with the length of the member is primarily associated with expansion of the metallic core. The expansion of the metallic core is due to the development of a corrosion product (rust) of the carbon steel core.

This crack should be investigated by the current procedure to determine if it requires a non-structural or structural repair.

Examination of the existing records of restoration and repair

The reason for examination of records of repair and maintenance of the elements of the central tower was to determine the longevity of the various repair and maintenance methods used since the Watts Towers became the property of the State of California. The historical record compiled from persons other than Rodia states on page 7 of the Ehrankranz report that Rodia had "kept up a constant program of maintenance and repair"[39] from 1948 to 1954. This indicates that the original construction had a limited life before corrosion of the metal core ruptured the mortar coating. Since the goal is to maintain the Watts Towers as a historical monument the repair and maintenance program cannot increase the thickness of the mortar coating that provides an alkaline environment over the carbon steel core. The maintenance goal is to maintain the original handiwork of Simon Rodia within the goal of preserving the structural integrity of the historic monument.

The record contains Appendix #5. This a draft of an addendum specification, dated 11 Oct 1978. This addendum does not discuss structural repairs but does state "Whenever there is doubt as to whether or not a structural member shall be replaced the doubt shall be resolved against replacement". Drawings are to be provided for each structural

replacement and documented "fissures" are to be filled with a non-alkaline cementitious material. The records search found no records in the data for the period when Appendix #5 was in effect. These repairs were supposed to be made distinguishable from the handiwork of Rodia. Repairs made subsequent to the 1983 Ehrenkrantz report did not distinguish between 1983 and subsequent repairs and the original Rodia handiwork. Correspondence from the current preservationist states, "it almost always shows that the State repairs failed to solve the underlying structural problem".

Hand written records for the dates of July 25, 1984 to Oct 12,1984 and Jan 7,1985 to May 13, 1985 are available. The notes of this time period implies that the Ehrankrantz recommendations were used for the many structural repairs in the center tower. These repair notes describe replacement of the steel armatures of the elements.

The computer files were searched for information on the center tower. The earliest records are for 1993. These entries are titled "clean/temp fill cracks". No records with a date of 1994 or 1995 were found for the center tower. These computer records are not very useful because they use column headings such as Tech #1 and Tech #2. There is no glossary to define these titles. The records print in landscape and one horizontal line contains two dates, one for Tech #1 and Tech #2. The printout may indicate that Tech #1 was used in 19 places in one member at one elevation above the base of the tower. The following day in this example states Tech #2 was used in 24 places on the same column, another column and a band at the same elevation above the base. The text for Tech #1 and Tech #2 appear to be describing a similar operation, replacement of a metal armature. This indicates that Tech #1 and 2 are not related to method A and B as described in the Ehrankrantz report.

The examination of the computer records found that the quality of the data and its accessibility made the goal of this task, determining the useful life of repairs, unattainable.

Recommendations for record keeping

Since the life of the historic monument is unlimited, not the 50 to 80 years as discussed in some correspondence, a record keeping program should be begun immediately. These records will be the data source for assuring that the structural conditions that existed at the time of the static load test are maintained. The recording of a continuing repair and maintenance program will allow future reviewers of the program to ascertain if the program is providing a "useful" life of the tower elements.

The first part of the record keeping is the preparation of explicit and definitive specifications for each operation that has been done in the past and for operations that are expected in the future due to environmental conditions such as corrosion of the metal core, wind storms and earthquake loading. These specifications should contain materials and execution. The materials should be chosen for their ability to act with the metal core as a composite having an adequate moment of inertia and an ability to slow the corrosion of the metal core of the element. The materials should be chosen for having a reasonable probability of their execution by workmen. An inspection program of the execution of the specifications should be implemented. This inspection program should be by a qualified person. The entire process should be recorded by the inspector in text in a data program that can be searched by key words such as location in plan and height, element, a key word for the specification section used and a key word for either structural or non-structural repair.

The data program should be chosen for its compatibility with current computer operating systems. The computers used for storage of this data should be upgraded on a several year cycle to assure that the data is accessible for an unlimited time in the future.

There should be a clear understanding of all involved in the stabilization, maintenance and repair operations of the Watts Towers that these operations are not limited in time. The specifications should be updated regularly as knowledge of effectiveness of the operations is gained. The core of knowledge must be available to all future personnel as the personnel will have a normal turnover.

If these recommendations for record keeping are adopted it must be recognized that all records must be included in the data bank. There cannot be private or outside files. There cannot be addendums to the current specifications. If revisions are needed for special conditions, these revisions should be incorporated in the current specifications. Enforcement of the specifications by the assigned inspector is essential for the preservation of the monument.

Risk assessment

There is little evidence that the risk assessment made in the 1983 Ehrankrantz report should be modified. The single available data point is the results of the "Goldstone" static load test and estimates of the structural condition of the tower at the time of the test. The Los Angeles Department of Building and Safety report cites visible damage to key structural members of the towers at the time of the static test. The current structural engineer consultant provided a personal communication that no structural repairs, Method B, were needed since about year 2000. If this data is taken alone, there would be a reason to reduce the previous risk posed by wind or earthquake loading.

This possible reduction in risk can be offset by statements in Appendix #1 and 2 that indicate the risk assessment given in the 1983 Ehrenkranz report was totally misunderstood.

That risk assessment was made for an earthquake intensity of about one-tenth of a "design event intensity". The spectral intensity that was correlated with the static test has an annual probability of occurrence of 2 percent. This annual probability of occurrence is about one-tenth of the local design intensity used in the National Earthquake Hazard Reduction Program of 1983. A change was made to the 1983 Ehrankranz specifications in 2/1990 for Critical Structural Members. Method B was given a low priority for a repair scheme and required special permission for its use. Notes were found in the data review that stated "doubts were to be resolved against structural (Method B) repairs" due to an anticipated loss of historic fabric.

Appendix #1 states that the structural consultant to Ehrenkrantz gave an opinion that 50 percent of the historic fabric would have to be removed during the repair process. This statement cannot be found in the Ehrenkrantz report. It could be rationalized as a response to a question about what historic fabric would be lost if the earthquake intensity exceeded that used for the risk assessment. Appendix #1 states incorrectly that the risk assessment was assuming the occurrence of a design intensity earthquake.

Appendix #1 states that a 50 to 80 year life of the Watts Towers is expected. The annual probability that an earthquake-caused displacement will equal that displacement caused by the static load test is 2 percent. The low priority for Method B repairs reduces the expectation that the structural integrity of the towers has been maintained as equal to the condition at the time of the static test. This offsets the information that recent investigations have not found continuing corrosion of the metal core.

The statement in the 1983 risk assessment was related to an exposure time of the Watts Towers to a seismic risk posed by its geographic location. This statement does not imply that the existence of the towers is equal to an exposure period. The occurrence and intensity of an earthquake at a single location in Southern California is a random event and time of occurrence or intensity of ground shaking cannot be predicted. Probabilities can be estimated by statistical methods but it must be recognized that these are estimates, not predictions.

The expectation of a "life" must be related to the end of that life. What happens at that time? It is recommended that the need for adequate structural repairs be reviewed by the appropriate agencies.

Recommended revisions for improving effectiveness of repairs

The present system of structural repair does not include provisions for increasing the useful life of the repair. The term useful life is used because the original construction by Rodia did not provide a thickness of material (mortar) with an alkalinity that prevents development of an oxide of iron. The original thickness of the mortar surrounding the iron core was not adequate to extend the life of the core. This mortar forms a composite with the core that was adequate to prevent buckling under compression loading of the columns. The environment attacks the alkalinity of the mortar rendering it ineffective to prevent oxidation of the metal core. The carbonation of the mortar does not cause it to become ineffective as part of a composite element. The current specifications used do not specify a minimum thickness of the mortar to meet this dual criteria.

The use of a salvaged cover over the existing or replaced core is similar to the use of a tile in lieu of the original mortar cover. The method of how this cover is placed and bonded structurally to the partially covered core is not adequately described and no

inspection of the attempt to form a structural bond free from porosity and voids is made. The probable value of the tensile bond of the cover to the core has not been determined by physical testing. The probable behavior of the repaired element , using the current specifications, is likely very dissimilar from the behavior of the originally constructed element. The ability of the tile to provide a similar useful life of the metallic core as originally constructed is suspect. The tile has been exposed to an environment that has reduced its alkalinity to possibly neutral.

The current maintenance program of non-structural and structural repair is reducing the probability that the performance of the towers when loaded by gravity and earthquake is similar to that tested by the application of a static load. The decision to reduce the "reinforced concrete" structural elements to "tile clad structural cores" should be reviewed to determine whether this current program will lead to a satisfactory conclusion. It should be clearly understood that the static load test strength is equated to an earthquake shaking that has an annual probability of occurrence of 2 percent. The intensity of this event is one-tenth of the design level intensity used for design of new structures.

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