

THE GUADALUPE AQUEDUCT: HISTORICAL MONUMENT AT RISK

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Abstract. *Based on data obtained directly on the site, the current conditions of the Guadalupe Aqueduct are described. The aqueduct was constructed from 1743 to 1751 to carry water to the Guadalupe Sanctuary along approximately 10 km (6.7 miles). According with original descriptions the length of the aqueduct was 12 900 varas (10 700 m), in the first section, water runs through a shallow or underground channel; however, the main portion was elevated supported by 2287 arches. As part of this paper a resent survey was done, which shows that the first part is no longer exist, and only 1584 arches remain of which 887 are in good conservation condition, 369 are moderately damaged and 328 have severe damage o dilapidated. The results are compared with the information reported in other sources, mainly a book by Manuel Romero de Terreros written in 1949. Despite rehabilitation programs carried out so far, the deterioration of this National Monument is evident and far more advanced than that reported in past years. For instance from the year the aqueduct was completed in 1751 to 1949 the structure lost about 5% of its volume, in only 63 years the additional loss is about 30%. If this tendency proceeds in the next 30 years more than half may despair. Structural and ornamental parts -that no longer exist- are pointed out, for instance the water intake and reservoir at Tlalnepantla River, and two cofferdams at Amialco and San Rafael. Finally constructive and structural characteristics are established as a base to propose general procedures to ensure stability. It is concluded that: a) in order to preserve this monument a deep intervention is required by which damaged arches and buttresses must be restored, attain the stabilization of arches foundation with techniques of soil substitution, as well as mortar injection in cracks, and replacement of loss materials, b) the structural rehabilitation is not enough, a integral rehabilitation is required by means of social programs including ecological and cultural tourism, integration of landscape with the urban zone, and of course an effective protection of the monument which implies the commitment by the government for not open new roads or streets that may affect the aqueduct as happen in the recent past, which is the principal cause that several parts of the aqueduct not longer exist, and c) that the monument is at risk and its conservation is important for the city, at least a documental study shall be done.*

1 INTRODUCTION

The Guadalupe Aqueduct built from 1743 to 1751 was declared historical monument on April 7th 1982. The original length of the aqueduct according with data of that time was 12 900 *varas* (10 700 m). In the first section water runs through a shallow or subterranean channel; however, the main portion was elevated supported by 2287 arches. In its origin almost all the path was at sparsely populated areas, in contrast, to day the aqueduct is within a populated urban area of North Mexico City.

The Federal Law of Monuments and Archaeological sites [1] establish in the 2o article: “Is of public benefit, the research, protection, conservation, restoration and recuperation of the archaeological, artistic and historical monuments and the monuments sites” However in the case here analyzed the precept was not accomplished because the monument suffer increased deterioration and mutilations.

The main purpose of this paper is to describe the actual conditions of this colonial work, to point out that more than its protection the mistreatment was favored, and to propose general criteria for the conservation of the remainders.

A book by Romero de Terreros [2] describes the main colonial aqueducts in Mexico; one of them is the Guadalupe Aqueduct, the author reports damages and mutilations from that time, 1949. In addition it is known that from that time, periods of any care occur including the use of materials of the aqueduct in other works, until 2006 that was partially rescue from abandon. From this antecedent the specific goals of this paper are: a) to recognize the remainders of this aqueduct; b) to compare the actual condition to that reported in 1949; c) to analyze the constructive and structural characteristics; d) to establish estimates and opinions about the despaired parts; e) to propose general criteria for the preservation of the remainders, and f) to present a prospective analysis.

In the frame of the actual urban environment in the course of the aqueduct, the methods used were the study of historical, architectural and constructive background; the site examination of the remains in relation to the state of conservation, constructive techniques and characteristics of the materials; the analysis of the structure and the consideration of actual rehabilitation techniques for antique constructions.

2 HISTORICAL DATA

After several failed attempts and an unsuccessfully construction due to lack of quality, the beginning of the work of the aqueduct begin the 22th of June 1743 during the rule of Viceroy Count of Fuenclara and was concluded on the 30th of March 1751 at time of the first Count of Revillagigedo [3].

The main components of the aqueduct as was reported by Romero de Terreros [2] in 1949 are: Pool, water intake near Tlanepantla River at the village of Santa Maria it consist of a box construction with a vault, crowned by an opening as a small cupola. A basin constructed in 1720 to control the water flow in the opposite side of the river. A pool near the Amialco Bridge in the road to Cuauhtepic, only the basement was left as well as a stone statue of San Francisco. Near by, other statue in this case of Virgin of Guadalupe at that time in better conditions including original inscriptions in Latin. A pool located at the place call San Rafael Garden, with a classical niche that protects an excellent statue of El Salvador. At the village

of Timolanco, the archery starts consisting of 2287 arches of no more than 4.0 m of clear span except four with 7.0 m. The esthetic value of the aqueduct is mainly due to the pools, water boxes (structures to retain sand and other impurity) and fountains. From the many of these structures the fountain al Santa Isabel Tola is remarked, as well as the final water box near the Guadalupe sanctuary and the fountain in the front of the colonial temple dedicated to the Virgin of Guadalupe. An antique copperplate by Rivera Cambas [4] permits to visualize the original characteristics of the water box at the end of the aqueduct.

The same author, Romero de Terreros [2], reports several damages as well as openings to construct roads and streets at several parts, mainly: a) at the cross with Los Remedios River in which a siphon made of steel pipes was constructed to save the pass of water at the road to Nuevo Laredo, and b) a hydraulic work constructed by the year 1945 that cause the demolition of several arches.

3 ACTUAL STATE

Comparing with the state at 1949 the situation now is worse because several other cuts were made which affects the aqueduct. Seven cuts were identified mainly for pedestrian passages and streets, two of them are mayor cuts of several hundreds of meters, one for the elevated viaduct of Los Remedios and the massive hydraulic and urban works at the former Tlalepanlta River which is the cause of the disappearance of most of the upper part of the aqueduct. Some of the main components that no longer exist are: the pool and water intake, the original basin to control the flow, the pool al Amealco and the pool al San Rafael Garden.

Despite rehabilitation programs carried out so far [5], the deterioration of this National Monument is evident and far more advanced than that reported in past years. The existing reminders are: a) arches: 1584 of different dimensions, of this total 887 are in acceptable state of conservation, 369 with moderate damage, an the rest, that is 328, are severe damaged or ruinous, see Figure 1.



Figure 1. Photography showing severe deterioration at the base of some arches, location near the former Los Remedios River. (by the authors, November 2012)

b) buttresses: only exist 60 pair of buttresses of which 32 are well preserved, 24 with different degrees of damage and four ruinous; c) water boxes: 13 are conserved of which four are covered with the original dome and the rest with a modern concrete slab. The final distribution box was completely restored in 1970 however at present is in bad shape because of ground settlements and intentional mistreatment; d) fountains, only two remain, the one at Santa Isabel, see Figure 2, and the other near the former Los Remedios River, both of the fountains are not in function and very reformed; e) slabs with inscriptions: only there, the one at the water box at the end is in good shape because is made of alabaster, the other two made of soft stone are damaged and unreadable; f) added structures: two modern monuments at the Laredo Road cross, a symbolic modern monument with a flag pole, two modern chapels and an arch of reinforced concrete with structural deficiencies.



Figure 2. Photography showing San Francisco Fountain near the village of Santa Isabel Tola (by the authors, November 2012)

4 STRUCTURAL BEHAVIOR

At upper part of the archery, the arches were constructed with poor quality masonry with non labored stone and bricks in complete pieces or broken, with lime and sand mortar joints of good consistency. Other parts are made of irregular stones jointed with very poor mortar or mud. The parts that exhibits more consistency it is observed that good quality stones were used, some of them carved, and mortar of strong consistency. In relation with the foundation, only was possible to observe its shape in a few cases were excavations were made to form depressed pedestrian passages. The original foundation was only 0.30 to 0.50 m in deep, made with slab stones of appreciable dimensions with joints of lime and sand mortar or mud. It is evident that the low deep of the foundation propitiated that several trams of the aqueduct suffer sinking and deformations. This is a problem that continues because all the zones of antique lakes of the so call Valley of Mexico are not stable.

During the colonial period the constructors follow empirical rules from roman constructors [6]. The slender ratio is defined as the ratio of the clear span to the deep of the voussoirs which for better results was recommended to be between 10 and 20. A slender ratio less than 10 is a robust arch with a structural behavior as a wall. A slender ratio of more than 20 means a very slender arch that can fail suddenly. In the case of the analyzed aqueduct the slender ratio is 5 or less, only a few arches with 12. For this reason the arches of the Guadalupe Aqueduct are, in its majority, robust and the observed failures of some of the arches are not due to loads but to the settlements of the foundation and intentional harm [7], see Figure 3. The rule to establish the depth of the foundation was a tenth of the high at firm soil and a fifth of the high at soft soil. In the present case, the dept of the foundation should be, according with this rule, at least one meter, which was not accomplishes as was mentioned later. This is the main reason why most parts of the aqueduct are instable. It is concluded that from the beginning the structural conception was not correct; because in one hand arches are overdesigned, but in the other the foundation is scared.



Figure 3. Photography showing a failed arch due to settlements (by the authors, November 2012)

5 PROPOSAL FOR CONSERVATION

Tree facts are pointed out: a) because of the grow of the city the aqueduct is now located within the urban area, b) the aqueduct have a social value as an historical monument, and c) the aqueduct form a part of the landscape and may be a factor of social integration in the zone, see Figure 4.

Because of this the potential of this monument to improve the quality of live of the residents and visitors is out of question, for this it is necessary the protection and rehabilitation of the remainders of the aqueduct. A general criterion should consider three main precepts as follows: a) insure structural stability [8], b) the protection of the monument

to prevent further demolitions for the opening of streets and passages, and c) to rescue the improvements done and are in bad shape.



Figure 4. Photography showing a view of the Guadalupe Aqueduct at Ticomán (by the authors, November 2012)

General proposals in relation to structural stability:

1. Arches and buttresses with severe damage need first of all a re-foundation which can be attained with micro-piles or soil substitution with fluid refill. Once the stability of the foundation is ensured mortar injection of cracks and reposition of weak mortar and stones are required.
2. Arches with severe cracks and deviations need to be replaced previous scaffolding.
3. The part exposed to earth pressure due to road embankments need to be protected with reinforced concrete retaining walls.

6 PROSPECTIVE

From the above discussion it is apparent that for 1949 the aqueduct was interrupted in four parts losing about 30 arches, besides some components were damaged. To year 2012 the former interruptions were enlarged and seven new interruptions were added from 10 to 300m length, as a consequence 716 arches were demolished as well as other components. From this the volume of materials loss can be estimated: from the origin to 1949 the aqueduct lost approximately 5% of its volume; from that year to date an extra 30% loss occurred. If this tendency continues the aqueduct can loss in the next 30 years more than half of its volume and probably disappear in the worst scenery

The possible partial or total loss of this aqueduct may have not real consequences, as was the case of La Tlaxpana [9] and Belén aqueducts; however the historical and architectonic loss will be irreparable. Thus a plan for the rescue and conservation is necessary, or at least a complete documental study shall be elaborated including a detailed geometrical survey, deep architectonic and constructive studies, and professional photograph and tridimensional representations with specialized techniques.

The divulgation of the results of this study it is considered important because: a) to let know the main characteristics of the aqueduct, b) as a reference for future studies, c) as a base to search for the social sustainability of the zone and d) as a mater to take conscience about the possible consequences to other historical monuments. Several other aqueducts of the type and in the same region can be mentioned, for example: Zempoala, Los Remedios, El Sitio and Tepoxaco.

Zempoala Aqueduct, also known as Padre Templeque Aqueduct [10], is the most antique, built from 1543 to 1560, but the best preserved due to its good quality of design and construction. Los Remedios Aqueduct [11] is a singular case, the existing remains correspond to two different systems non of them actually function, the first of 1616 with the main component was a siphon (arcaduz) of which the observed remains are two oscillation towers known by common people as *los caracoles* (snails), the second system of 1764 consisting of two orders of arches but only one was actually completed. El Sitio Aqueduct [12] is more recent but the original length was more than 60 km (37 Mi) and the archery at the El Sitio Gorge, with four orders of arches is one of the highest in the world with 60 m (Nimes Aqueduct 49 m, Segovia Aqueduct 28m)

In each of the mentioned cases, including the Guadalupe Aqueduct, is common the abandonment and misuse including intentional damage by some people, see Figure 5. Other problem is graffiti which is difficult to solve because political and social aspects are involved. In order to gain better results it is necessary to involve the residents and visitors by means of cultural activities as well of historical tourism, for instance cultural contests as photography, panting and other techniques including in some parts street art. An other possibility that may be positive is to work in agreement with the involved official instances, the residents and institutions of higher education, working in multidisciplinary teams, mainly architecture, civil engineering, urbanism and other social sciences, to elaborate compressive studies and proposals for the integrated rescue and reutilization with the participation and compromise of all the parts involved.



Figure 5. Photography showing a water box and part of the aqueduct, damage and abandonment are apparent (by the authors, November 2012)

7 CONCLUSIONS

The Guadalupe Aqueduct is a vestige of main importance, however the monument is at risk and its conservation is important for the city, at least a documental study shall be done.

From its origin the volume of the aqueduct's work have reduced to approximately 35%, about 30% occur in the last 60 years, if this rate of deterioration continues in the next 30 years more than 50% will disappear and in a drastic scenario may be completely lost.

Despite the official programs to maintain this work damages and deterioration are present and in some parts is at risk of collapse. In order to preserve this monument a deep intervention is required by which damaged arches and buttresses must be restored, attain the stabilization of arches foundation with techniques of soil substitution, as well as mortar injection in cracks, and replacement of loss materials.

The structural rehabilitation is not enough, a integral rehabilitation is required by means of social programs including ecological and cultural tourism, integration of landscape with the urban zone, and of course an effective protection of the monument which implies the commitment by the government for not open new roads or streets that may affect the aqueduct as happen in the recent past, which is the principal cause that several parts of the aqueduct not longer exist.

The future of the aqueduct is uncertain because settlements of the soil continue, damage and deterioration increase and apparently there is scatter funds for its conservation.

It is mandatory a compromise of the official authorities in charge to avoid new cuts and partial demolition of the aqueduct.

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