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# Multidisciplinary Researches in Cultural Heritage Studies: An Approach on Akkale Cistern in Erdemli, Mersin

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**ABSTRACT**

Conservation, reinforcement and restoration of architectural heritage requires multidisciplinary approaches which should be organised in precise steps that are similar to those used in medical science. Architectural conservation decisions must rely on full understanding of the historical, material, structural, geological and environmental information related to the building and its setting. The aim of this paper is to discuss phases of a multidisciplinary approach applied to develop a conservation project for the ancient cistern building, located in Akkale archaeological site in Mersin (Turkey). Firstly, architectural description of the ancient cistern building in the light of current information revealed by archeological excavations is presented. Then, methods and technics conducted by each expert group are discussed explaining the main results obtained from each study. Finally, organization of multidisciplinary studies and results gained from each step are displayed through a flow chart diagram showing process of research and data from one phase to another to develop architectural conservation program.

## 1. INTRODUCTION

Conservation interventions on historic structures should be respectful to its historical, cultural, architectural and aesthetic values. Integration of scientific methods into repair and preservation programs of immovable cultural assets (from archaeological ruins to historical monuments) have been emphasized by modern conservation approaches since the beginning of the century through a number of important charters and documents. Techniques to be selected for the safeguarding of historical building should base on scientific investigation and be respectful to its authenticity and historical significance values. Athens Charter for the Restoration of Historic Monuments (1931), which was an initial international manifesto adopted in International Congress of Architects and Technicians, drew attention to the significance of multidisciplinary approaches in conservation studies stating as “architects and curators of monuments should collaborate with specialists in the physical, chemical, and natural sciences with a view to determining the methods to be adopted in specific cases” (Athens Charter, 1931). Few decades later, it was realized that the scientific methods proposed for conservation and repair works could result in unexpected negative impacts on the monument itself and cause irreversible loss in its historical value as in the case of Parthenon in Acropolis. Thus, principles for scientific investigations and choosing appropriate techniques during conservation interventions were discussed as a topic by itself (Naycı, 2010). Over three decades later; Venice Charter, another significant international doctrine was adopted during II International Congress of

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Architects and Technicians adopted in 1964. Some of the issues adressed by Venice Charter, was to link restoration architects with technicians, to strengthen multidisciplinary works and to collaborate for training of experts in conservation programs (Jokilehto, 2013). The 2. principle draws attention to application of scientific collaborations as "The conservation and restoration of monuments must have recourse to all the sciences and techniques which can contribute to the study and safeguarding of the architectural heritage". Similarly, the Charter concludes with emphasis on shared collaboration during and after such scientific researches in article 16: "In all works of preservation, restoration or excavation, there should always be precise documentation in the form of analytical and critical reports, illustrated with drawings and photographs. Every stage of the work of clearing, consolidation, rearrangement and integration, as well as technical and formal features identified during the course of the work, should be included. This record should be placed in the archives of a public institution and made available to research workers" (ICOMOS, 1964). Although there were a number of attempts to update principles of Venice Charter in following years, it was translated to 28 languages; referenced by several international documents, doctrines and programs; and gave way to different countries during their national administrations (Jokilehto, 2013).

Finally as it was stated by ICOMOS (2003) through the document "Principles for the Analysis, Conservation and Structural Restoration of Architectural Heritage", the conservation approach of historic buildings requires organisation of studies in precise steps that are similar to those used in medicine: "Anamnesis", includes condition assessment of structures as well as understanding historical alterations and modifications, "diagnosis" refers to evaluation of damage categories and causes of decay; "therapy" includes development of a comprehensive conservation program and "control" includes monitoring of the building to evaluate post-intervention phase. Similarly, "Interventions should be based on full understanding of all kinds of actions (forces, deformations, alterations, etc.) that have caused damage or decay; and the ones that will affect it in the future" (ICOMOS, 2003).

Today, the main National authority, which is responsible from the identification, registration and conservation of immovable cultural assets in Turkey, is the Ministry of Culture and Tourism. The authority has developed a number of legislations for grouping of immovable cultural assets, phases of conservation and restoration projects, and principles to be applied in conservation implementations. Conservation techniques for immovable cultural assets are classified as "maintenance, simple repairs and comprehensive repair (restoration)" in Principles Act No. 660 (T.C. Kültür ve Turizm Bakanlığı, 1999). Comprehensive repair (restoration) techniques are detailed as "consolidation, liberation, reintegration, renewal, reconstruction and moving interventions" according to definitions presented in Vencie Charter.

Therefore; a comprehensive conservation program on immovable cultural assets and historic structures should encompass phases of 'historical research' to understand its authentic uses, historical changes and alterations occurred in time; 'architectural surveys' to understand principles in traditional material use and construction techniques, 'comparative analysis' to evaluate significance of the building among its historical, functional or cultural similars; 'condition assessment' to understand material and structural degradations discussing types of problems, sources of decays and impact levels; 'structural analysis' to evaluate original performance and existing structural safety of the building; 'environmental analysis' to understand physical, geological, hydrological, climatic conditions that have affected phsyical condition of the building as well as its vulnerability against future natural risks.

However, implementation and management of the multdisciplinary collaboration during both survey and implementation phases is a challenging task. There are various techniques that can be applied on historic buildings or structures during scientific and technical researches -from non-destructive, to slightly destructive or destructive methods-. Scientific techniques that are relevant for a historic building may cause unexpected adverse impacts for another. Thus, most appropriate and convenient technique for that building must be selected according to its cultural and physical condition considering its current state (i.e., whether buried or on ground), carrying capacity (i.e., structural soundness) and vulnerability (existance of fragile artworks -stucco, mosaic, etc.). Alternative strategies should be developed and a consensus should be achieved among experts and conservation specialists during multidisciplinary approaches. Within the light of these information, the purpose of this paper is to discuss phases of a multidisciplinary approach applied to develop a conservation project for the ancient cistern building, located in Akkale archaeological site in Mersin. Being located in Tırtar of Erdemli town today, Akkale was an important port facility of ancient Olba Territorium[1] during classical times. There is one of the largest public cisterns of the Olbian region located in the centre of this facility, which is called as Akkale cistern. Showing a valuable example of ancient hydraulic engineering of its region, a feasiblity project was conducted by a team of experts from Mersin University and Rome 'Tor Vergata' University including archaeologists, conservation architects, structural engineer, geological engineers and city planner. Archaeological excavations have been conducted by Mersin Museum (in the name of Ministry of Culture and Tourism) with the scientific consultancy of KAAM (Research Centre for Cilician Archaeology). The purpose of the Akkale Feasibility Project, which has been supported by Çukurova Regional Development Agency[2], is to develop a visitor management plan for the whole site, to start architectural conservation program for the ancient cistern and display its architectural and technological features as a self-displaying museum for visitors.

[1] "Olba Territorium" is the ancient name of region located in Göksu (Kalycadnos) and Limonlu (Lamos) Rivers today. The region was ruled within an unified political control over centuries beginning from the classical times. Today; there is a high number of ancient settlements of towns, castles, rural compounds survived from that period up to day

### 1.1. Description of Akkale Cistern

Archaelogical surveys conducted by Mersin University Research Centre of Cilician Archaeology (KAAM) and Mersin Museum since 2017 proved that ancient settlement of Akkale was an important port facility (Figure 1).

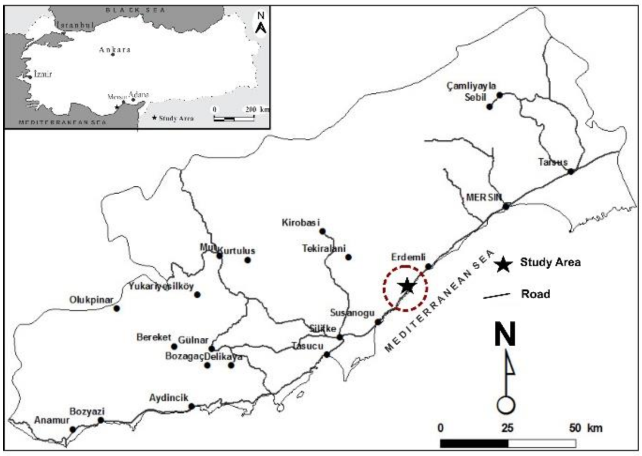


**Figure 1.** Location of Akkale Archaeological Site in Mersin (Tağa & Güler, 2018)

There were harbour bath, accommodation facility (inn), public cistern, monumental tomb and remains of religious buildings (Aydınoğlu & Mörel, 2017). Archaeological surveys have also revealed remains of water channels leading from Elauissa-Sebaste Korykos water work towards Akkale. Moreover, there are remains of additional water structures excavated nearby Akkale cistern indicating that there was an integrated water distribution network through the settlement (Figures 2 and 3).

**Figure 2**. Akkale Cistern and buildings in Akkale

**Figure 3.** Interior view of Akkale Cistern

Akkale cistern is one of the remarkable and well preserved buildings of the whole site. It has a rectengular size with 21.53 m × 36.40 m dimensions and 9.80 m interior height. The main construction technique of the cistern is cut-stone masonry walls, with two rows of arcades supporting the vaulted superstructure. The cistern finishes with flat roof located onto the three rows of barrel vaults. There are top windows and remains of cut-stone roof claddings on the cistern roof. The roof top might have been utilized for additional rainwater harvesting into to the cistern, since there is remarkable catchment capacity with its roof size. Each arcade has 7 arches supported on stone pillars (Figures 2 and 3). There are 3 windows located on each east and western wall, which were probably used to control, to provide daily light and fresh air for interior.

The ancient settlement has been developed on a sloped hill; so the cistern is semi-buried into the rocky ground by using the advantages of the topography. The northern wall is supported by terrain itself, while the southern wall is carried by thick cut-stone masonry walls with 1.50 to 1.80 m width. Interior walls and arches are plastered until the beginning level of vaulted roof. In order to avoid water pressure, there are additional loadbearing stone pillars located on southern and eastern walls. Whereas, the western wall was supported by a second wall attached from outside. This wall has two functions: as a walking platform to access both to the roofs and to the staircases leading into the cistern. Secondly, it helped support the flooring levels of the stone paved street located at the west. The recent excavations has revealed stone paved main street of the settlement, which might have lead to the harbour at the coast (Naycı et al., 2017).

Due to the steepy profile of the hill; the street was constructed in means of leveled platforms embedded into the topography. Each level was supported by two continous walls on eastern and western side, one of which was the exterior supportive wall of the cistern. The street was also utilized for water distribution from the cistern to the fountains located at the western wall, and bath building located at the south. So, the water coming from the main cistern was distributed to other buildings through the pipes following the slope of the street. Since original level of the street were destructed under soil, regular cavities can be observed under the street. These may have belonged to either rainwater harvesting or water drainage system, since such adjustments are common for Roman city infrastructures.

The recent archaeological campaigns in Akkale have shown that, this port settlement was also provided with water from Elauissa/Sebaste-Korykos water conveyance system (Aydınoğlu & Mörel, 2017; Bildirici, 2009). After

[2] The research program named as "Feasibility Research for Survey, Conservation and Presentation of Akkale (Erdemli) Archaeological Sites" has been supported by Çukurova Regional Development Agency and Mersin University during 2017-2018. The archaeological campaigns and survey results have been regularly updated since then.

the Limonlu and Tırtar aquaducts, a branch of surface water channel leads to to Akkale settlement. So, the two chambered cistern located at the north of main public cistern must have functioned as castell of the public cistern, where the water taken from Elauissa/Sebaste-Korykos water work was settled in here before it was leaded to the main cistern. The remains of water channel leading towards the main cistern can be seen after excavations. There are five pipe cavities observed from the inside which are related with water inlet-outlet. According to their levels of location, shape and size, it can be proposed that the rectangular cavities located at northern walls are related with cut-stone channels bringing water to the cistern from the southern cisterns. There are two circular holes on the western walls, which might have housed pipes providing water from cistern to fountains and bath building along the street. There is another circular hole located at the lowest level on eastern wall, which might have another water outlet from the cistern.

## 2. METHODOLOGICAL APPROACH AND CONTENTS OF SCIENTIFIC RESEARCHES

Akkale cistern, which functioned as the main reservoir of this harbor facility, deserves detailed analysis in order to understand interconnected water distribution system of the settlement and develop appropriate visitor management and architectural conservation program. For this purpose multidisciplinary research approach is carried out both in building and settlement scale to understand the role of Akkale cistern within the water distribution system of the settlement. Experts from archaeology, architectural conservation, structural and geological engineering disciplines developed a multidisciplinary research program in order to investigate the cistern building and its nearby environment in detail.

The research stages include archaeological documentation and architectural surveys of the building and the site; historical uses, alterations and restitution survey of the cistern; condition assessment related to material degradations and causes of decay; material analysis on plaster and mortars used in the cistern; geological and geotechnical research in order to understand the physical relation of the cistern with the topography it was burried into; structural analysis to evaluate original resistance capacity of the building (with water) as well as its structural safety in present situation. Detailed discussions regarding technics and methodologies applied in each research; results gained from each phase and flow of information from one phase to another are presented in following:

**-Architectural Documentation and Building Surveys**: Archaeological excavations around the cistern revealed important architectural information and traces related to original condition of the building. Following, detailed measured surveys including architectural plans, cross sections, internal and external elevations and documentation studies related to site maps have been conducted by using optic measurement and aerial photogrammetric techniques. Survey drawings are utilized to evaluate architectural details, material use and construction techniques of the cistern. They also provide base maps for restitution proposals and condition assessments studies in further stages (Figure 4).

**-Condition Assessment:** Condition assessment is the initial step in conservation studies since it helps understand existing situation and preservation state of the historic structure by using visual observation techniques to identify material decays and structural deformations. This fundamental phase gives direction for further qualitative and quantitative analysis to be conducted, methods and techniques to be selected to achieve comprehensive conservation decision-making process for the building. Having completed architectural documentation and building surveys; visual observations related to material decays and structural deformations are conducted. The cistern was constructed with cut-stone masonry technique by using mortar as the main binding material. Interior facades were plastered in order to prevent water leakage. Since the main construction material was stone; technical classifications of "Glossary of Stone Deterioration" prepared by ICOMOS was utilized to determine types of decay forms (ICOMOS, 2008).

Accordingly, five groups of decay types are identified from slight to severe impact level. First group represents slightest level of material decay including color alteration and surface depositions such as black crusts and salination. Second group is slight decay level, which includes moderate biological colonizations and macro-vegetation. Third group includes stone degradation and detachment problems, which are classified as pitting, alveolization, flaking, sugarization and contour scaling. Fourth group identifies material cracks and fissures. The fifth group represents the most severe level, which shows material loss and partial destruction. Having identified material decay groups, material deteriorations observed in the building were mapped onto the architectural survey drawings (Figure 5).

**-Comparative Material Analysis:** Waterproofness is one of the primary design criteria applied during construction of historic water structures. Water conveyance systems such as galleries, channels or storage structures such as cisterns, reservoirs were constructed either in hard rocky beds or plastered with hydraulic finishing materials to prevent water leakage. Physico-mechanical performance of plasters and mortars used in historic masonry water structures had hydrophobic properties rather than other types of buildings. Interior facades of Akkale cisterns were covered with plaster until the beginning level of vaulted superstructure. Plaster lines show maximum height of water when the cisterns were filled with water in its full capacity. In order to understand physico-mechanical properties of plasters and mortars used in Akkale cisterns; a comparative analysis with the rest of building structures in the site was conducted. For this purpose, plaster and mortar samples from three water-related structures (Cistern 1, Cistern 2 and street fountain) and material samples from non-water-related structures (the tomb, wall remains) have been taken from the site and sent to the Conservation Laboratory of Ministry of Culture and Tourism in İstanbul (Figure 6). The laboratory investigations on material samples include identification of physical components and aggregates through stereo-microscope visualization, petrographic analysis to understand their physico-mechanical aspects and chemical analysis based on calcination and soluble salt tests (İstanbul Konservasyon Laboratuarı, 2017).

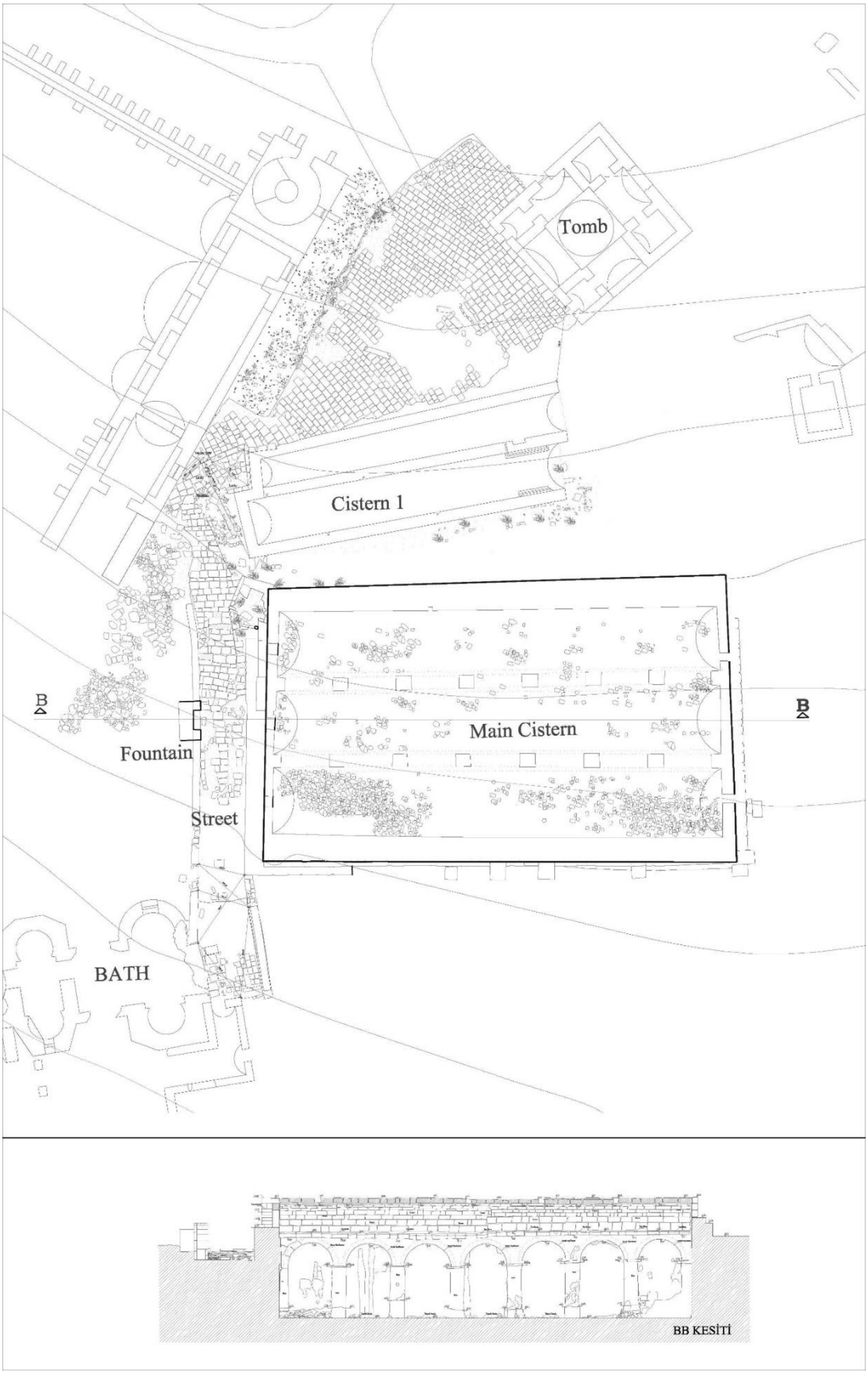


**Figure 4.** Survey drawings of the cistern

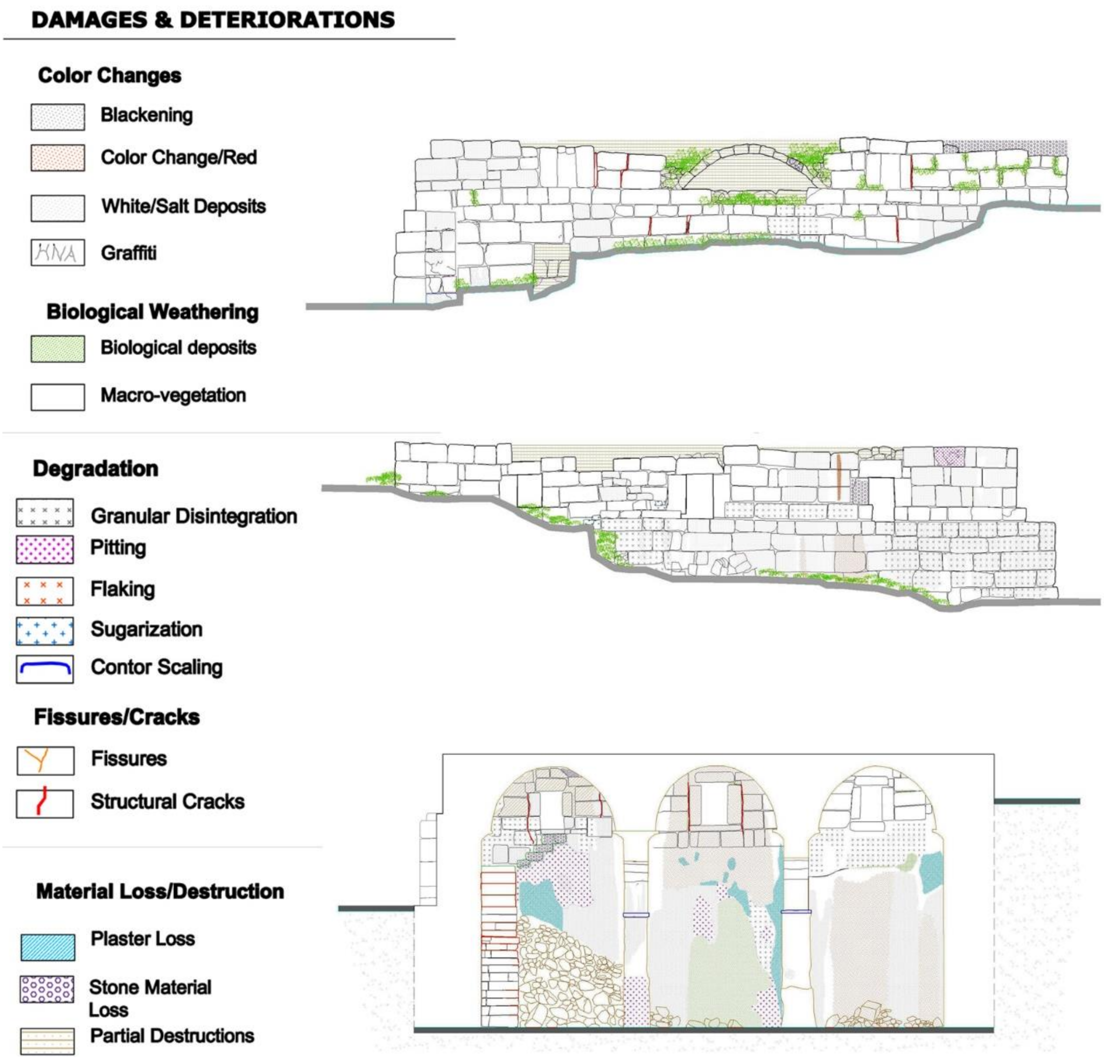


**Figure 5.** Mapping of material deteriorations observed in the building

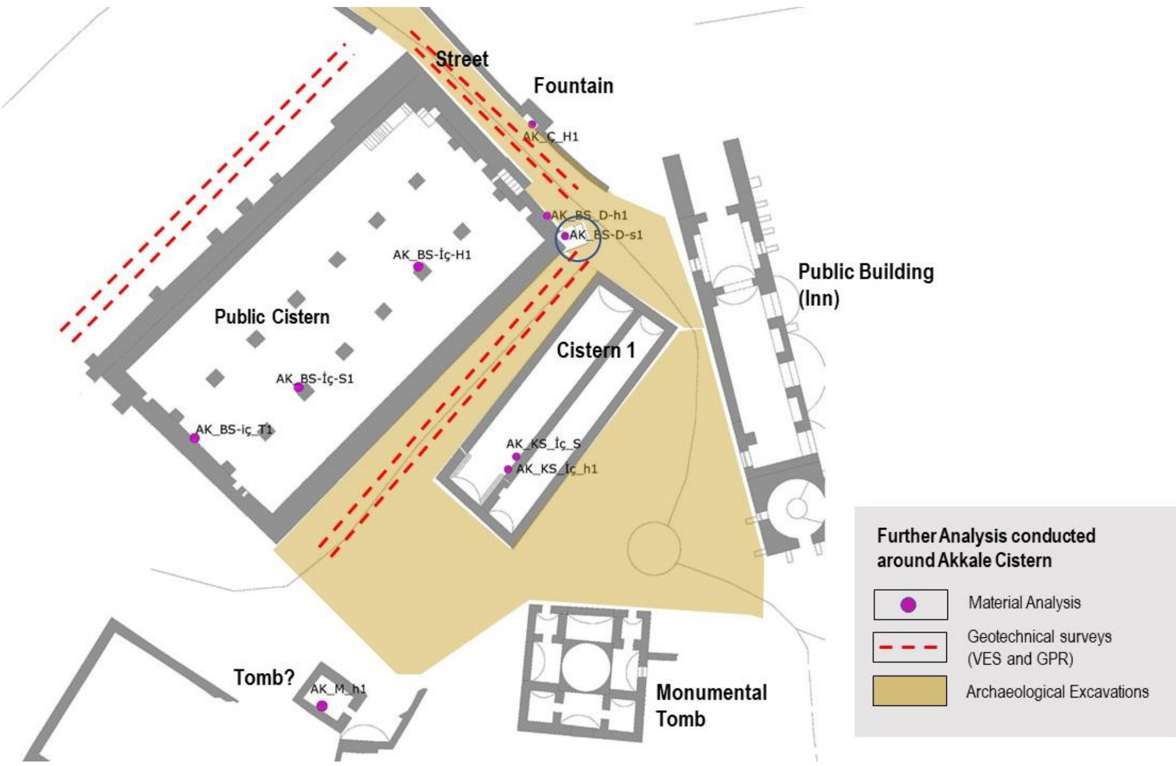


**Figure 6.** Locations of further field investigations applied in the site

**-Geological and Geotechnical Surveys:** Further site investigations related to geological aspects of the site have been conducted in order to compare geomechanical properties of limestone used in masonry construction of the cistern with rocky formation of its close environment and to understand its relationship with the terrain it was constructed into. Non-destructive techniques (NDT) have been preferred for geological and geotechnical researches, since the cistern is located in an archaeological site (Figures 7 and 8). Sonic velocity and Schmidt hammer resistivity tests were performed on the locations chosen on the building. Samples from rocky ground showing similar lithological aspects with stone material used in construction of cistern building were examined through laboratory tests to provide geological data during structural analysis works. Since the cistern was settled into the topography, another NDT method of Vertical Electrical Sounding (VES) technique was applied in order to scan ground resistivity of the cistern and its environs. Ground Penetrating Radar (GPR) method was applied around the cistern to understand boundary of lateral walls inside the rock bed and how much it was buried into the ground (Tağa & Güler, 2018).

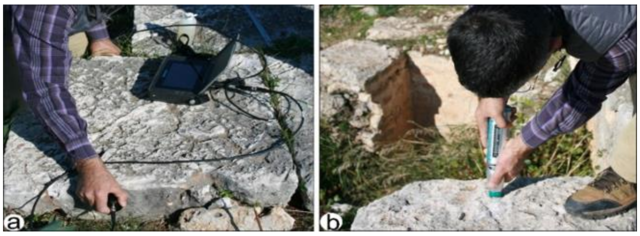


**Figure 7.** Sonic velocity and Schmidt Hammer tests applied on rocky ground (Tağa & Güler, 2018)

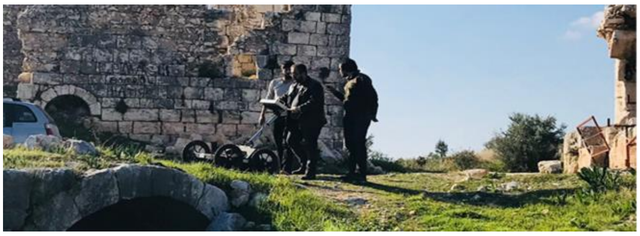

**Figure 8.** Geophysical investigations around cistern (Tağa & Güler, 2018)

**-Structural Analysis:** The structural condition assessments focused on the cistern building encompass field observations on structural deformations, structural analysis on original (with water) and existing situation (in relation with its environment) of the cistern, laboratory tests to understand its structural behaviour and structural safety. The results are evaluated to develop proposals in order to guarantee structural safety of the building during architectural conservation studies, possible reinforcing and strengthening activities in local critical parts[3] (Abiuso et al., 2019). Besides, preventive measures that should be taken in order to guarantee structural safety of the building during possible cleaning activity inside and local excavation activities outside the construction are suggested. In the light of geological data provided by geotechnical studies, structural models have been prepared to display structural behavior by using FEM methods (Figure 9).

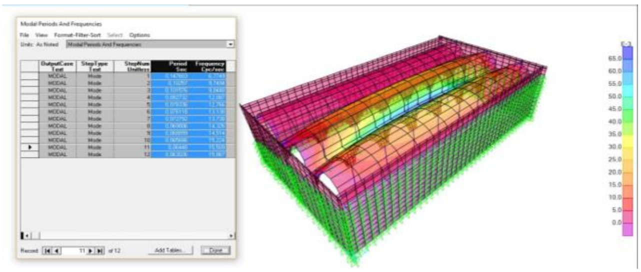

**Figure 9.** Model response and vibration mode of structural elements (Abiuso, et al., 2019)

## 3. RESULTS

Architectural, material, geological and structural analysis carried out by each group in Akkale case, provided a comprehensive and detailed information that can be integrated into architectural conservation interventions of the cistern building as well as safety precautions to be taken during archaeological excavations and visitor management studies. Multidisciplinary researches conducted by different technical groups provided flow of more accurate information from one phase to another during analysis and condition assessment studies (Figure 10). Overall evaluation of these results provide definition of a detailed conservation program including phases of interventions and appropriate techniques that should be chosen for cistern building.

Laboratory tests on sample materials taken from the site provided information on physico-mechanical properties of original stone, mortar and plaster materials used in masonry of cistern building. Stone samples possess biomicrite limestone characteristics, which are very common in the ancient structures of the region. Mineralogical-petrographic analysis on mortar and plaster samples have showed that there are two types of material design. Three of the samples taken from interior facades of cisterns have pinkish color; and include aggregates of limestone, brick pieces and brick powders with binding material of clay. These plaster samples support the idea that brick powder was used to increase hydraulic performance of materials applied in surfaces of water structures. The other three samples have scolor and indicate cement as the binding material with aggregates of limestone and brick pieces. These results have provided quite satisfactory information related to design of repair mortars and plasters in conservation interventions.

The geological, geotechnical and geophysical data gained during field tests and laboratory tests provided accurate data to be utilized during structural analysis by using FEM method. Similarly, evaluations on condition assessment of cistern building could be more reliable due to the results of structural safety analysis. By altogether evaluation of geological and structural analysis, intervention decisions related to environmental control (water drainage), structural repairmen and reinforcement of the cistern, as well as precautions related to management of construction site during cleaning and restoration studies could be prepared.

[3] Detailed discussions regarding structural analysis are presented in sepaate paper: (Abiuso et al., 2019)

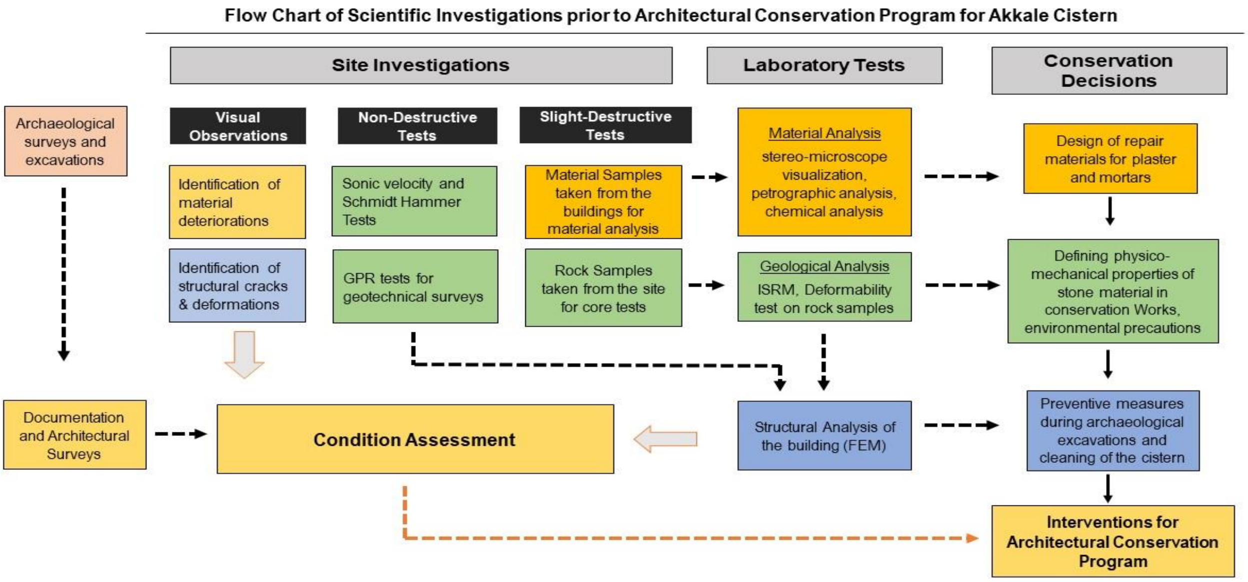


**Figure 10. Flow chart of scientific investigations prior to architectual conservation program for Akkale Cistern**

## 4. CONCLUSION

As stated through international doctrines from the beginning of modern conservation paradimgs in the beginning of XX century, conservation of cultural heritage is a multifaceted complex challenge since every historic structure possesses unique situation of physical condition statement. The scientific survey, analysis, evulations -which will end up comprehensive conservation program and intervention decisions- require quite good organization of technical experts, selection of appropriate technics for that building, flow of accurate information among phases of scientific researches. Among cultural assets; archaeological settlements are most fragile ones since most of structures are in ruins state and there are constant survey and excavation interventions, which reveal new information each time. This also necessiates a comprehensive management and monitoring program before, during and after conservation implementations.

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