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Architectural Inventory and Building Condition Assessment Research on Masonry Structures of Kanlıdivane Archaeological Site, Mersin

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ABSTRACT

Conservation and structural strengthening of historic masonry structures is a long and challenging process which necessitates technical expertise and constant budget to keep conservation works regularly. Thus, one of the priorities of cultural heritage management programs must focus on regional and site scale monitoring programs in order to evaluate structural and physical condition assessment of cultural assets, classify risk categories based on their damage levels and develop urgent and preventive precautions accordingly. This will keep historic structures in safe; and prevent severe destructions and loss of significant values by regular maintenance works within the technical and fiscal capacity of the institutions. Within the light of this information, the purpose of this paper is to discuss results of the architectural inventory methodology developed for Kanlıdivane Archaeological Site (Mersin) to provide a systematic condition assessment approach as a supportive assessment phase for decision-making process of comprehensive architectural conservation program to be developed in site scale.

1. INTRODUCTION

Kanlıdivane is one of the important historic sites of Erdemli town, which possesses rich and diverse monuments that belong to Hellenistic era, Roman, late Antiquity, Byzantine and traditional periods. Majority of architectural heritage of the site constitutes historic masonry structures, showing different stone masonry construction techniques of the region (Figure 1).

The conservation status of monuments varies from semi-destructed structures to well preserved ones. Since there hasn't been any archaeological excavation campaign or architectural conservation program in the site yet, degradation and damage levels in the structures increase because of atmospheric and environmental conditions over time. The purpose of this paper is to discuss on research entitled as "Architectural Survey and Condition Assessment of Masonry Structures in Kanlıdivane Archaeological Site1" which aims to develop an architectural documentation approach including integrated condition assessment methods as a preliminary impact assessment phase for decision-making process.

Figure 1. Kanlıdivane archaeological site

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1.1. Structural Condition Assessments on Masonry Structures

Building condition assessment methods include techniques of documentation, visual observation, filed tests and laboratory tests. There is a number of visual damage assessment methods, which can be applied for rapid and visual observation on historic masonry structures. Damage analysis helps to understand impact category and its level of the building, while detailed crack analysis provides to understand structural safety of the building. Damage assessment is generally related with earthquake occasions so most of the assessment methods are classified as pre-earthquake and post-earthquake evaluations. The damage categories in masonry structures are generally classified from moderate to very severe (damaged) categories (Kaplan, 2010: 54):

-1. Degree (Neglectable): Fissures and tiny cracks in masonry walls, plaster loss, stone material loss starting from top of the walls

- 2. Degree (Moderate): Multiple cracks in several walls, large pieces of plaster loss, local destructions in chimneys

- 3. Degree (Medium): Multiple and continuous cracks in several walls, loss of roof tiles, torsions in chimneys

- 4. Degree (Severe): Loss of axis in walls, local destructions and roofs and floors

- 5.Degree (Very Severe/Damaged): Local or total destructions in the building.

Some approaches in damage assessment focus on source of the incident (settlement process, earthquake, landslide etc) and types of forces acted on the building (lateral forces, compressive forces, etc) that caused structural deformation in the building. In these approaches, detailed crack analysis is implemented evaluating the size, location and distribution of the cracks on the building. Building components are subdivided into its external and internal; horizontal and vertical structural elements to understand structural mechanisms in detail (Binda et al., 1999):

- Overtuning; of front walls, corner, upper external wall,
- Collapse: outer wall, staircases,
- Failures: in lintels, shear failures in piers, internal walls, external walls
- Cracks: masonry vaults, closed openings, chimney pipes

1.2 Condition Assessment Studies on Historic Masonry Heritage

Historic masonry structures have been exposed to long- and short-term impacts of various decay types which cause material deteriorations and structural deformations. Severe levels of material deteriorations and degradations can cause structural failures in time if they constantly take place on critical structural elements. A historic building which has been evaluated as "structurally safe" according to structural assessment studies might be in risk because of severity of material deteriorations. So, condition assessment approaches in in cultural heritage studies may differ according to the purpose of the study. If the condition assessment targets to make a rapid analysis on post-disaster evaluation such as earthquake destructions to identify emergency precautions in a historic setting or to understand impacts of seismic activities in high risky zones, then structural damage level provides brief evaluation on urgency levels. If the target of the research is to develop a management program for a group of buildings or setting; overall analysis including material deteriorations and structural assessments helps to develop comprehensive monitoring and conservation program including decisions related to activities from regular maintenance to structural repairments. Another important evaluation criteria is to understand the vulnerability of historical structure against sources of threats:

Vulnerability factor is the exposure of the structure or site section against the source of threats or impacts. The vulnerability research changes according to the location and characteristics of the threat category such as closeness to geological discontinuities, liability of landslides, earthquake zones, location/exposure to coastal processes. Some of this information is researched from the past events such as floods, heavy rainfalls, etc. Vulnerability is assessed according to probability of outcome of the event and location to the source of threats according to one or more criteria defined above (Naycı, 2009). These assessments can be carried out according to a specific impact group such as:

-*Earthquake*: evaluation criteria on past information and inventory of events, geological conditions, vibration monitoring, etc.

-*Geological Discontinuities (Landslides, Earthquakes, Rock falls, Soil Settlements)*: Past information and inventory of events regarding Geological and soil conditions (water drainage capacity, etc), Hydrology, Human interventions (deforestation, modification of profile, etc)

-*Floods*: Statistical information on past incidents, Identification of abnormalities

-*Coastal Process:* Geomorphological changes, Human modifications (coastal structures, etc)

-*Macro-vegetation:* Analysis on current condition and impact on structure (whether symbiotic relationship or not); Vegetation characteristics

-*Visitor Impact (Fire, Vandalism, etc)*: Evaluations on accessibility by people, location, intensity of vegetation, Security etc

2. METHODOLOGY

Kanlıdivane (Kanytellis) archaeological site is located in 2 km. north of Ayaş town in Erdemli. The ancient settlement was developed around geological Pit (obruk) called as 'Kanlıdivane Obruğu'. The historical background of the settlement dates back to Hellenistic Periods (Durugönül, 2001). Archaeological remains and monumental structures that are observed throughout the settlement today belong to Hellenistic, Roman, Late Antiquity and Medieval periods. The centre of the settlement must have developed around the Pit, since most of the public buildings such as Hellenistic tower, church buildings, cisterns were located here. Center of Kanytellis has been embraced with necropolis areas including a number of sarchopagus, tomb structures and monumental tombs with temple plans. The settlement has extended necropolis areas housing rich number of tombs with different typologies. There are remarkable examples of temple-tomb structures located in this section including tomb of Aba, which dates back to 2. century (Aydınoğlu, 2015,33).

The research methodology of the "Architectural Survey and Condition Assessment of Masonry Structures in Kanlıdivane Archaeological Site" project is based on systematic survey of damage categories observed in historic masonry structures. For this purpose, the research process includes two survey levels of condition assessment studies as site level and building level evaluations. Phases of research have been organized as pre-field preparations, field surveys and analysis stages.

2.1 Pre-field Studies

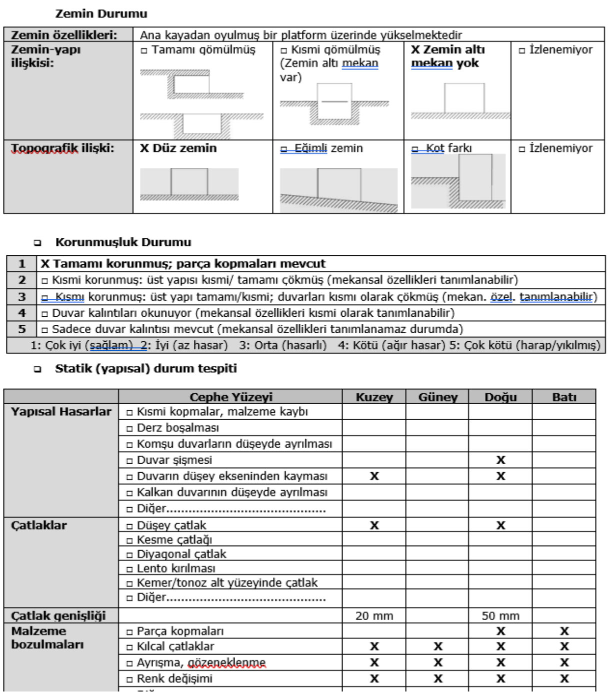
The research starts with preparation of base maps including 1:1000 scale site plans and Google Earth satellite images obtained from institutions -Municipality and Regional Conservation Council-. The raster data was processed in the Geographical Information System software (ArcGIS 9.2.2) to develop base maps. Secondly, historical data in order to understand physical changes in the site were gathered through travelers notes, previous documentation studies and old photographs. Literature surveys on previous archaeological surveys, environmental and geological studies are conducted so as to understand natural changes in the environment and to evaluate vulnerability of the site against natural and human impacts.

Secondly, architectural survey sheets, which would be used for systematic survey of condition assessment of historic structures, were prepared (Figure 2). The survey data included information related to:

- Structural system: Material use and construction technique, vertical supporting elements, horizontal supporting systems, thickness of masonry wall, binding material, plan geometry, historical interventions,
- Relation with terrain: Building- ground relationship, topographical condition.
- Conservation Level: Impact assessment classified as 'good, moderate, medium, severe, destructed/damaged' levels.
- Condition Assessment: Mterial deteriorations and degradations, structural deformations, Crack analysis,
- Macro-vegetation, environmental problems, etc.

In the final phase of pre-field surveys; the GIS database has been prepared in order to analyze results of field surveys. Spatial distribution of condition assessment results also provides significant information to compare intensity of problems and define priorities in site management plans.

[2] The GIS process of the Project results have been carried out in GIS Laboratory of Mersin University.



Zemin Durumu

Zemin özellikleri:	Ana kayadan oyulmuş bir platform üzerinde yükselmektedir			
Zemin-yapı ilişkisi:	□ Tamamı gömülmüş	□ Kısmi gömülmüş (Zemin altı mekan var)	X Zemin altı mekan yok	□ İzlenemiyor
Topografik ilişki:	X Düz zemin	□ Eğimli zemin	□ Kot farkı	□ İzlenemiyor

□ **Korunmuşluk Durumu**

1	**X Tamamı korunmuş; parça kopmaları mevcut**
2	□ Kısmi korunmuş: üst yapısı kısmi/ tamamı çökmüş (mekansal özellikleri tanımlanabilir)
3	□ Kısmı korunmuş: üst yapı tamamı/kısmi; duvarları kısmı olarak çökmüş (mekan. özel. tanımlanabilir)
4	□ Duvar kalıntıları okunuyor (mekansal özellikleri kısmi olarak tanımlanabilir)
5	□ Sadece duvar kalıntısı mevcut (mekansal özellikleri tanımlanamaz durumda)
	1: Çok iyi (sağlam) 2: İyi (az hasar) 3: Orta (hasarlı) 4: Kötü (ağır hasar) 5: Çok kötü (harap/yıkılmış)

□ **Statik (yapısal) durum tespiti**

	Cephe Yüzeyi	Kuzey	Güney	Doğu	Batı
Yapısal Hasarlar	□ Kısmi kopmalar, malzeme kaybı				
	□ Derz boşalması				
	□ Komşu duvarların düşeyde ayrılması				
	□ Duvar şişmesi			X	
	□ Duvarın düşey ekseninden kayması	X		X	
	□ Kalkan duvarının düşeyde ayrılması				
	□ Diğer..				
Çatlaklar	□ Düşey çatlak	X		X	
	□ Kesme çatlağı				
	□ Diyagonal çatlak				
	□ Lento kırılması				
	□ Kemer/tonoz alt yüzeyinde çatlak				
	□ Diğer..				
Çatlak genişliği		20 mm		50 mm	
Malzeme bozulmaları	□ Parça kopmaları			X	X
	□ Kılcal çatlaklar	X	X	X	X
	□ Ayrışma, gözeneklenme	X	X	X	X
	□ Renk değişimi	X	X	X	X

Figure 2. Architectural Inventory Sheets

2.2 Field Surveys

The field surveys include collecting detailed architectural data in building and site scales. Site documentation study includes systematic survey of condition levels and damage categories of historic masonry structures by using inventory sheets. The Kanlıdivane archaeological site has been opened to visitors after the completion of site presentation project completed by Ministry of Culture and Tourism in 2015. After the implementation studies; intense vegetation over buildings and remains were liberated and their visibility have been increased. West and northern sections of the site became accessible by visitors through conduit routes and direction signages. In its present situation, accessibility of the site is limited due to intense vegetation of nature in the western part, while northern and western sections are quite visible and accessible. The historic structure-visitor contact may pose various risks for each group especially if there are severe structural damage categories. Thus, the systematic survey in site scale by using inventory sheets have been conducted on buildings located around the geological pit (obruk) and in the visited zones since these areas are more vulnerable against visitor impacts.

The site level inventory research has provided comparative analysis on historical masonry techniques applied in different monuments, vulnerability of each structure in relation with their location in the site and exposure to natural and geological vulnerabilities, damage categories and their impact levels of structures. Spatial distribution of survey results and assessments in the site could be visualized by data spatially processed in GIS medium (Figure 3).

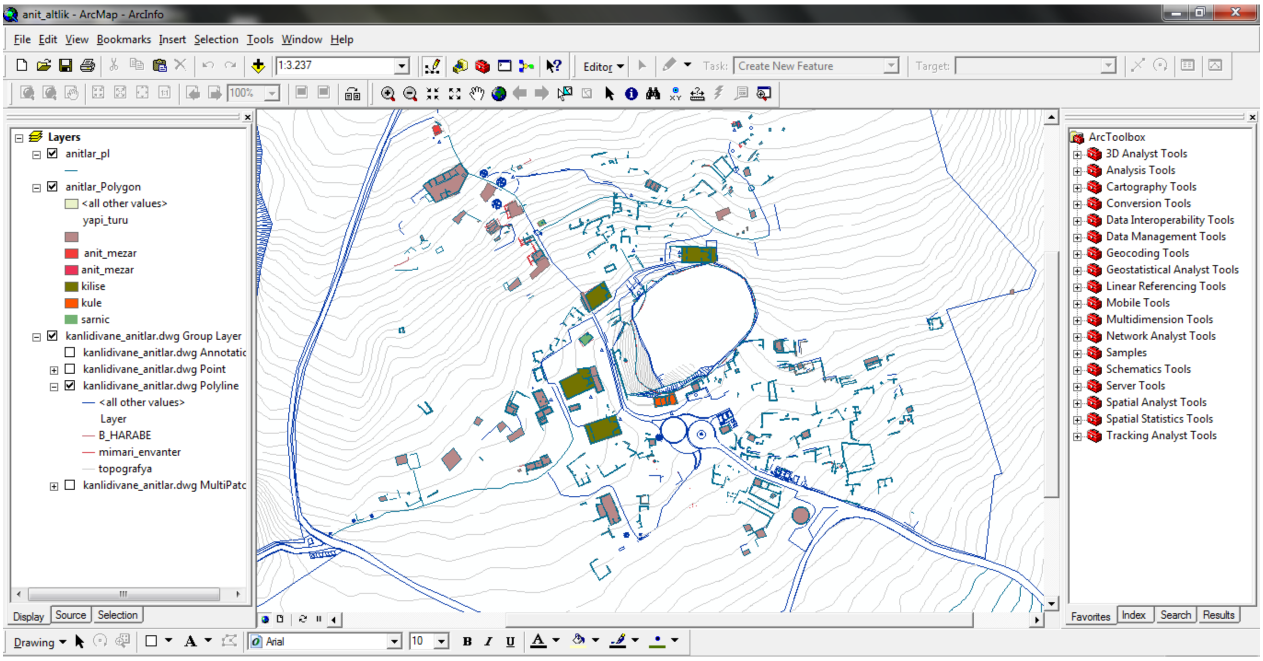


Figure 3. GIS database for spatial distribution of condition assessments

Research of building scale condition assessment has encompassed studies related to architectural survey (Figure 4) by using optical measurements techniques3, visual documentation, and detailed mapping of material deteriorations and structural deformations onto building survey drawings. Building scale studies have been conducted on the selected examples according to evaluation of site level inventory studies: The Hellenistic Tower, Tomb No 1, Tomb No 2 and Church no 4. These monuments represent characteristics of different masonry techniques applied during different historical periods (Hellenistic, Roman and Byzantine).

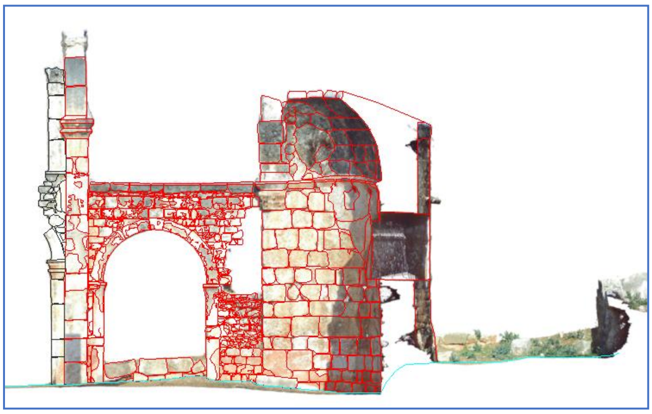


Figure 4. Architectural Survey on selected buildings

The categories of material deteriorations and degradations have been classified according to Glossary of Stone Deterioration" prepared by ICOMOS since the main construction material of the monuments is stone material (ICOMOS,2008). Material decay and degradation types categorized in five groups (Figure 5) from slight to severe impact levels:

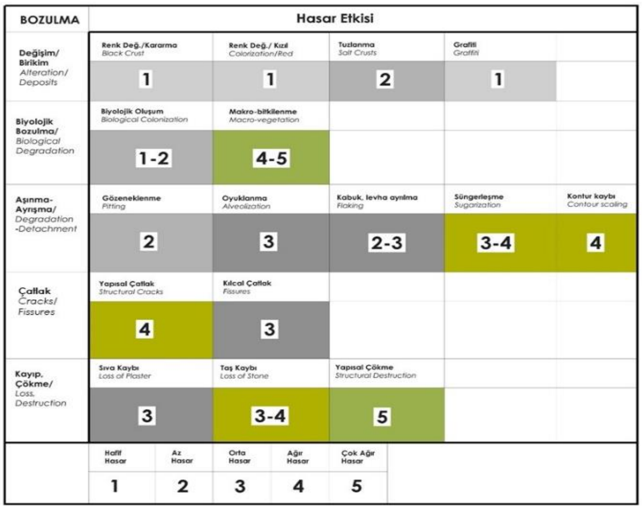
1.Slightest level: Material decay including color alterations, surface deposits, black crusts, salination, etc.

2.Slight-to-Moderate level: moderate biological colonizations, micro-vegetation.

3.Moderate Level: stone degradation, detachment problems, such as pitting, alveolization, flaking, sugarization and contour scaling

4.Moderate-to-Severe Level: Material cracks and fissures.

5.Very Severe Level: Material loss and partial destruction.



BOZULMA	Hasar Etkisi				
Değişim/ Birikim *Alteration/ Deposits*	Renk Değ./Kararma *Black Crust* 1	Renk Değ./ Kızıl *Colorization/Red* 1	Tuzlanma *Salt Crusts* 2	Grafiti *Graffiti* 1	
Biyolojik Bozulma/ *Biological Degradation*	Biyolojik Oluşum *Biological Colonization* 1-2	Makro-bitkilenme *Macro-vegetation* 4-5			
Aşınma-Ayrışma/ *Degradation -Detachment*	Gözeneklenme *Pitting* 2	Oyuklanma *Alveolization* 3	Kabuk, levha ayrılma *Flaking* 2-3	Süngerleşme *Sugarization* 3-4	Kontur kaybı *Contour scaling* 4
Çatlak *Cracks/ Fissures*	Yapısal Çatlak *Structural Cracks* 4	Kılcal Çatlak *Fissures* 3			
Kayıp, Çökme/ *Loss, Destruction*	Sıva Kaybı *Loss of Plaster* 3	Taş Kaybı *Loss of Stone* 3-4	Yapısal Çökme *Structural Destruction* 5		

	Hafif Hasar	Az Hasar	Orta Hasar	Ağır Hasar	Çok Ağır Hasar
	1	2	3	4	5

Figure 5. Impact levels of material deteriorations and degradations in building scale

Building scale assessment studies base on visual observation techniques during field studies. The results have been mapped onto the architectural survey drawings (Figure 6).

[3] Optic measurement devices (Total Station) from Faculty of Architecture and open access softwares for photographic rectification analysis have been utilized during building surveys and architectural photogrammetry studies.

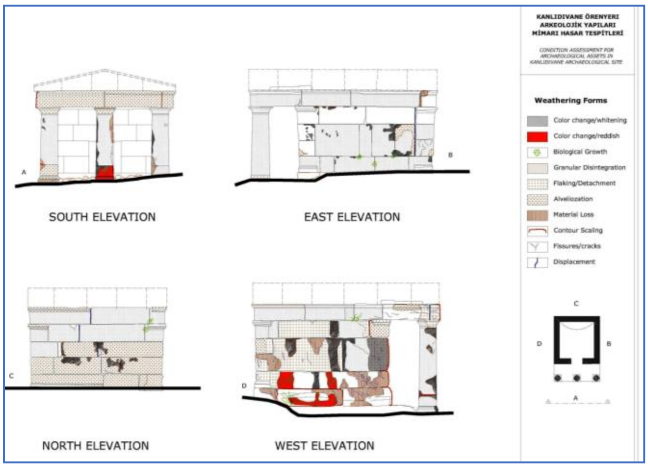


Figure 6. Mapping of material deteriorations and degradations on architectural survey drawings

3. RESULTS

Results of building condition assessments conducted in site and building level researches are presented in relation with evaluated derived and processed from one phase to another.

3.1 Historical Masonry Technics

There are two types of masonry construction techniques observed in the site as 'polygonal' and 'isodom' technique. Polygonal masonry technique was typically applied during Hellenistic era in the region. The Hellenistic Tower (which takes this name because of its construction technique) is one of the best survived examples of this era in Kanlıdivane. The corner stones selected from big size cut stones were used to make the system more rigid. The wall sections among the corner stones were constructed in polygonal technique. The irregular geometry in polygonal coursing provided more advantage in distribution of load when contributed to isodom technique (Figure 7). Roman period structures were constructed with cut-stone masonry technique in isodom style (Figure 8). There are monumental tomb examples survived from Roman period since most of them were converted or reused during late Antiquity period. The late Antiquity and Byzantine period buildings were constructed with smaller size rough cut stone masonry. The churches of the site, most of the residential buildings were constructed in this style. There are historical interventions added to these buildings generally. The wall section consists of double layered cut-stone filled with infill material. The masonry techniques applied in different periods affected structural performance of the buildings. The analysis has shown that construction technology related to wall sections, stone material use, coursing technique played important role in the structural performance of the building. There are still Hellenistic and Roman period buildings that are in good state while most of late Antiquity and Byzantine period structures have been severely damaged. The wall thickness in relation with height of the walls, was important in structural performance.

Figure 7. Hellenistic period Tower constructed with polygonal masonry technique in Kanlıdivane

Figure 8. Roman period Monumental Temple constructed with isodom masonry technique in Kanlıdivane

3.2 Comparative Condition Assessment on Site Level

The second criteria that affected structural performance and condition level of the monuments were their locations in the site and relationship with the ground during construction phase. Some of the was location in the site. The most severe natural risk in the site is the geological discontinuities. Previous geological surveys conducted by Güler and Tağa in the Kanlıdivane Archaeological Site have shown that there are severe geological discontinuities problems including landslide movements especially around the geological pit (Güler & Tağa, 2011). They also observed locations of geological crack lines because of past earthquakes (Figure 9). The limestone morphology of the ground makes it more vulnerable because of geological discontinuities and abrasion impact of surface and ground water. The fallen wall pieces from the archaeological site into the geological pit supports this analysis.

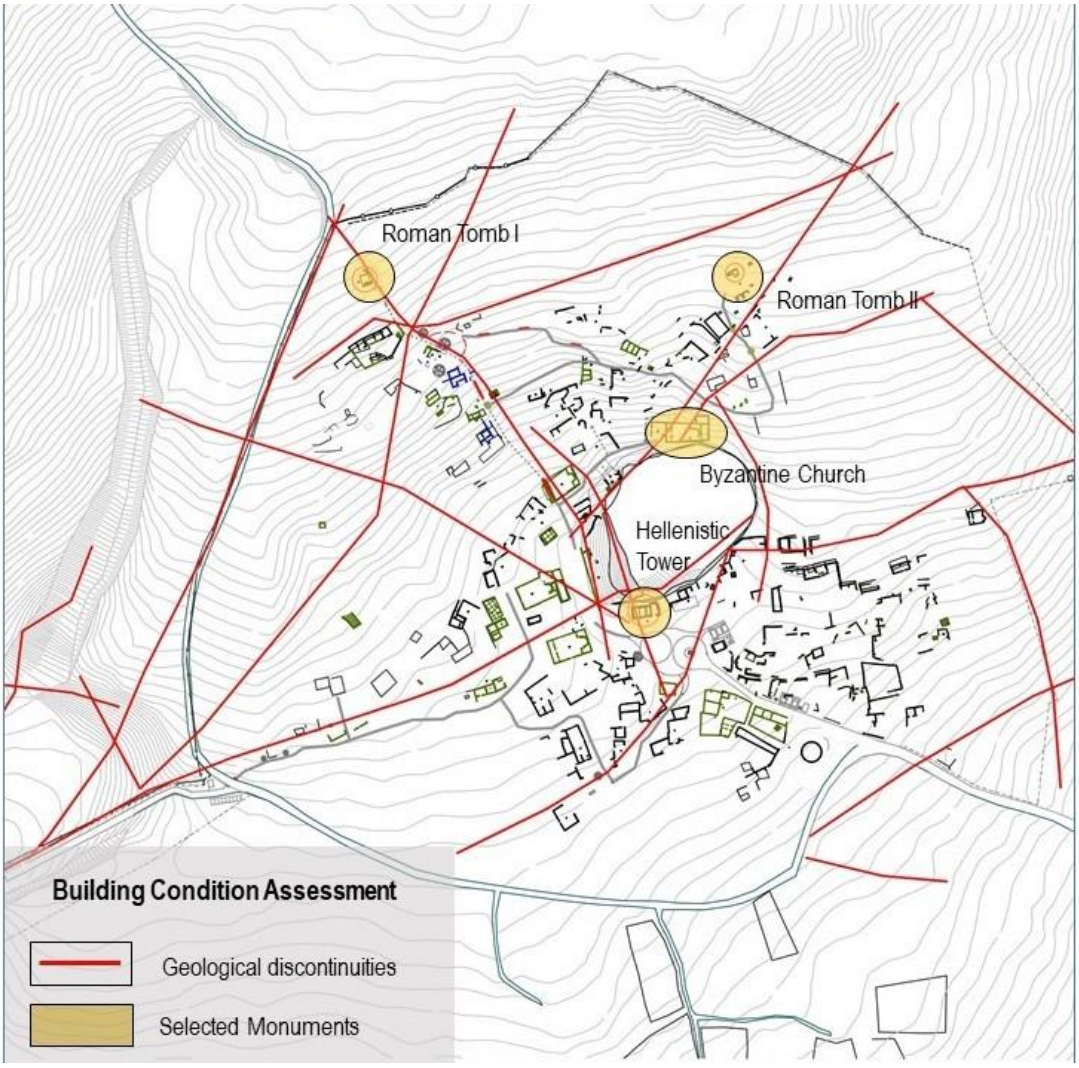


Figure 9. Locations of historic monuments selected for building condition assessment research in relation with the geological discontinuities in the site

Results of comparative analysis on building condition assessments conducted on selected monumental buildings (Hellenistic Tower, Roman Tomb I, Roman Tomb II, Church) have shown that the monuments constructed on rocky platforms located away from the geological pit or past earthquake lines are in very good condition (Roman Tomb II). The monuments constructed around the geological pit, are in severe danger since the landslide movement is still active. The Hellenistic Tower with its polygonal masonry technique and geometrical proportions could survive better when compared to Byzantine period church although it was constructed centuries before. Lastly, the Byzantine church with its weaker masonry wall section have been destructed and architectural integrity have been lost. The building has totally lost its southern façade located by the pit and the superstructure. The apsis section was gradually preserved with its domed superstructure.

3.3 Condition Assessments in Building Level

Detailed building condition assessment studies on selected monuments provided information related to structural mechanism acted on the building components in relation with environmental and geological factors.

Roman Tomb no I (Aba's Monumental Tomb) is located at the north of the geological pit. It is one of the landmarks of Kanlıdivane. The main construction technique of the building is cut stone masonry, with mortar as the binding material. The superstructure has gable roof form with stone claddings. It is supported by cut-stone barrel vault and then filled with rubble stone to gain planar roof surface. The vault identifies entrance of the main chamber in the south facade, which is covered with pediment at the roof level. The last row of cut-stones in masonry walls were constructed in architrave style while corner stones were finished with Corinth capital styling. Although the architectural integrity has been still preserved, there are severe problems in building scale. There are material deteriorations and structural deformations especially in the west and north walls. There are severe cracks on the north wall, which have caused destruction of stone materials into two. This shows probability of high impulse aroused by lateral forces or settlement problems. Since the monument is located very close to one of the geological discontinuity lines in the site, the structural degradation risk has been proven by external factors. The monument should be included into architectural conservation program immediately, before losing its structural integrity since it is one of the rare examples that sill keeps its architectural and structural unity.

Roman Tomb no II (The tomb with Trisylos Prostylos style) located at the north east of the site was constructed on a rocky platform located away from the pit and geological discontinuities. It is one of the well-preserved buildings of Kanlıdivane. Tomb no II (The tomb with Trisylos Prostylos style is located at the northeast of the site. It has square plan with 4,20 x 4 m. dimensions. It is located on rocky platform. The roof was supported by barrel vault which covers the top of the main chamber (cella). The tomb is identified as Trisylos Prostylos tomb by Kaplan (2015) since there are three columns located at the entrance façade. These columns are connected to each other and to the main building with architraves and stone lintel blocks. Today; the roof has flat surface covered with earth. The vaulted roof was filled with infill material. There are remains of stone block located on the top of southern wall, while rest of them were fallen from the building. Kaplan suggests that these remains display existence of pediment wall, so roof may have originally finished with gable roof form (Kaplan, 2015, 82). There are material deteriorations in slight to moderate level. Preventive precautions on the monument and environmental control (such as keeping the rainwater away) can provide a longer and safer time for the building.

The Hellenistic Tower, located at the south edge of the geological pit with its remarkable polygonal masonry technique has been suffering from structural cracks occurred in the corners of the building. The superstructure of the building and upper wall sections have been already destructed, but planimetric layout is very well preserved. The building must be included into structural reinforcement program such as filling with repair mortars and retrofitting interventions in order to avoid the vertical wall sections to fall apart from each other. The Hellenistic Tower is the oldest masonry technique in the region and one of the rare examples of its similars. The Byzantine church no 4 located at the north edge of the geological pit material degradation process has already lost its southern wall and main roof covering the main hall of the building. The weak wall sections (when compared to Hellenistic and Roman period construction technique) and limestone morphology of stone material used in the walls causes severe deterioration problem because of the atmospheric conditions and rainwater. The standing walls are facing sugarization and contour scaling problems in some of the structurally critical points such as door and window lintels. This may cause partial destructions in the existing walls or dome section of the apsis part. Therefore, the building must be included into architectural conservation program for both structural repairment and material conservation interventions.

4. CONCLUSIONS

The conservation of historic masonry structures necessitates multilevel research and survey analysis related to material deteriorations, structural deformations and mechanisms acting on the building, past events that caused alterations or destructions in the building, future evaluations according to environmental risks and vulnerability of the monument against these threats. All the impact factors and damage levels must be evaluated with "condition assessment" methodologies. These studies will provide development of comprehensive conservation and management programs both in site or regional levels to keep masonry monuments in safe; prevent severe destructions and loss of significant values by regular maintenance works within the technical and fiscal capacity of the institutions.

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