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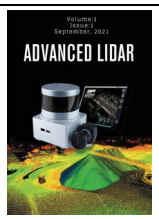

3D Laser Scanning and Photogrammetric Measurements for Documentation of the Facades of Mardin Castle, Türkiye

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Research Article

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Abstract

Mardin Castle is a cultural heritage of approximately 900 years and is located in the 1st Degree Archaeological Site. The castle has an east-west extension and contains Roman-Byzantine artifacts as well as many structures from the Islamic period (Mervani, Akkoyunlu, Artuklu).The entire length of the building is approximately 850 m when viewed from the south side at a right angle. Architectural documentation of the façades of such a gigantic building is a subject that requires a long time and effort with traditional methods and has a high risk of error. The main purpose of this article is to document the ruins of the southern facade of the Mardin castle and the rocky cliffs with architectural drawings. For this purpose, it has combined different analytical and investigation techniques such as terrestrial laser scanning, photogrammetry and observational analysis. In the study findings, facade surveys of the facade of the castle were obtained. The results of the study confirm that methods such as terrestrial laser scanning technology save a great deal of time and effort spent in the process of documenting huge structures such as castles.

1. Introduction

Terrestrial laser scanning technology and technologies for photogrammetric techniques provide great convenience for obtaining architectural drawings of gigantic structures. These techniques save a great deal of time and effort in buildings that are not easy to take architectural measurements and produce architectural drawings in traditional ways. Moreover, these methods are especially important as they minimize the error rate (Balzani et al., 2001).

Especially during natural disasters and wars, it has always been considered important to document such archaeological sites and to preserve all relevant information and details (Alptekin & Yakar, 2021). Today, with the increase in earthquake events in our region, as in many cities in the south, it has become a national duty to protect the heritage (Ay,2018). It is seen that many historical castles, especially Gaziantep Castle and Diyarbakır Castle, have been damaged or destroyed due to the earthquakes experienced in our country in the recent period. In this context, it is an urgent requirement to record and document the architectural features of these historical buildings (Karataş et al., 2023).

Terrestrial 3D laser scanning has become one of the most important methods for high resolution 3D documentation of structures today. But the benefits of laser scanning are still underestimated by professionals. Today, many studies have been carried out on the digital documentation of structures with terrestrial laser technology and it has been determined that positive results have been obtained (Alptekin et al.,2019; Gabriele et al.,2010; Fröhlich & Mettenlaiter, 2010; Georgopoulos et al.,2004; Guldur et al. al.,2005; Grussenmeyer et al.,2008; Oruç & Baş, 2021; Alptekin & Yakar, 2021;). However, it is seen that there are not many studies in the literature on the documentation of huge areas such as castles by terrestrial laser scanning method. One of the few documented studies; Naanouh & Stanislava (2021)

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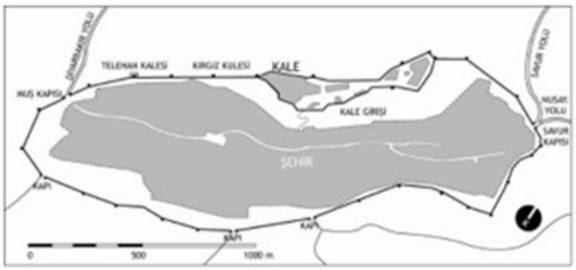
used a combination of terrestrial laser scanning and photogrammetry to create a three-dimensional model and digital documentation of Beaufort fortress (Arnoun, South Lebanon). The study results demonstrate the potential for the integration of terrestrial laser scanning and photogrammetry to be used in 3D digital documentation and spatial analysis of the Lebanese Citadel and its huge sites (Kabadayı & Erdoğan, 2022; Alptekin et al., 2022). He explained that this combination minimized the time, effort and error rate. Another example is Pane et al. (2020) used advanced laser scanning systems with a combination of different tools to document as accurately as possible the possible damage mechanisms and the complex geometric system of the castle of Pescopagano, which was severely damaged in the 1694 earthquake. In the results, they compared the results of using these techniques together with traditional methods and explained their benefits.

In the literature, there is no study documenting the architectural features of the castle structure in the city of Mardin. The main purpose of this article is to document the ruins of the southern facade of the Mardin castle and the rocky cliffs with architectural drawings. This study is an important study in terms of revealing the architectural facade drawings of Mardin Castle, which is the symbol of the city. The study evaluates the results of the combination of terrestrial laser scanning and photogrammetry to create digital documents of the facades of the Mardin castle. Laser scanning produced point clouds in the vertical direction, while photogrammetry produced planar images. Such tools have proven their effectiveness in scanning huge areas such as castles. Photogrammetry allowed to complement visual data for parts of buildings that were difficult to obtain by laser scanning (Erdoğan et al., 2022). The method presented in the study forces us to consider extending the terrestrial laser scanning method with other tools. This article provides examples of the beneficial use of laser scanning and proposes an extended theory.Mardin Castle; east side 1200 m., west 1180 m. It was built on a flat area on a rocky hill at a height. It is a location built on the upper part of the land on which most of the city rests (Dolapönü ,1961; 1972; Gabriel ,1940; Karataş et al.,2023c; Yakar et al., 2008; Yakar et al., 2009 ; Yılmaz &Yakar, 2016). This area rises from the point where the slope ends, separated by steep cliffs. As far as the topography allows, the castle is entered from the south, from a point almost centered on the area on which the castle is located. This entrance is reached by a steeper ramp and a staircase at the end (Karataş et al., 2023d; 2023e; Oruç & Öztürk, 2021).

2. Method

The study was carried out in two stages. Various field studies were carried out by visiting the building site. Then, the collected data was transformed into data on which architectural drawings can be produced in the office environment.



(a)

(b)

Figure 1. a) Mardin castle site plan sketch b) Aerial view of the castle (Mardin Metropolitan Municipality, 2023)

2.1. Data collection

The fortification wall, which is a cultural heritage of approximately 900 years, and the building remains on it, as well as the rocky formation in the southern cliffs, need to be documented precisely and completely. In this context, it was decided that it would be an effective and correct method to document the cliffs, fortification wall and building remains through the 3D point cloud to be obtained by using the laser scanner (Laser Scanner). The complete scanning of the Mardin Castle's south facade fortification wall remains and the rocky cliffs was carried out in two stages. First, the remains of the city wall and the rocky formation on the southern slope were scanned with a laser scanner and turned into a 3-dimensional point cloud (Figure 2).

In this context; Leica Geosystems brand ScanStation C10 model 3D laser scanner was used for the overall measurement of the building (Figure 3). When the device is examined in terms of general technical features; It can document with wide angle scanning and photography, 360º horizontal X 270º vertical. It also has the features of detailed and precise scanning and photographing of these regions by focusing on the defined partial areas and surfaces. The device can scan 90% reflective surfaces up to a distance of 300m. It is 50k dots/second. The efficient working ambient temperature of the device; It is between 0º C and 40º C. The device cannot operate at temperatures close to, below or above these values. The camera integrated into the device has a resolution of 4 megapixels and has the ability to take up to 260 photos of the scanned area at each station. The photographs taken by the device during scanning were essentially

requested to color the scan data and to detail the scanned surface by giving texture. For this purpose, the tool can be used together with the point cloud, but it can also be used externally by transferring it from memory to other computers. Commands and data related to field usage and scanning results of the device can be followed and intervened from the LCD screen on it. There is also the option of connecting the device to an external portable computer during field work. In this way, field scans can be followed simultaneously from the screen on the computer to be connected. There is 80GB of integrated memory space on the device, and the digital data recorded in this memory area in the field is transferred to the Sony Vaio Brand (8GB Ram, Intel i7 processor) portable computer at the end of the day.

Figure 2. Sample photograph of documenting the rocks of the south façade cliff section with a laser scanner (Mardin Metropolitan Municipality, 2023)

Many stations have been set up with laser scanners on the southern slope and upper part of the building. The connection between the stations is provided by introducing at least 2 and 3 common reference points (special manufacturing targets that the device can detect) with the previous station. In this way, a reference network consisting of target points was established throughout the structure. This reference network; Using the Sokkia brand Set 530 RK total station(Figure 3) device, the laser scanner was read simultaneously with the field work, and a coordinate network of the reference points was created. In this way, possible station aggregation or data loss problems in laser scanner data are prevented.

In addition, control and reference measurements regarding certain parts of the building (mosque structure, bastions, certain points of some main pillars, etc.) were taken with the total station device. The limited parts of the building that are too narrow for the laser scanner to work and the references cannot be read were documented using a total station. Remains of buildings, rock formations, caves in the cliff, and fortifications were measured in every situation that allowed measurement. It was tried to enter some sections (dehlis, cistern, etc.) with the help of specially equipped expert mountaineering teams. Detail measurements with rare sections that cannot be read with laser and total station devices; It was measured with a Leica brand, Disto A5 model laser distometer at long distances. Short distances, on the other hand, were measured with a tape measure and recorded on-site and simultaneously. Detailed measurements were taken with tape measure in the architectural elements and the detail drawings were made manually on metric papers in the field. The detail measurements taken were evaluated together with the laser scanner data and the detail drawings of such architectural elements were made in the office environment. Detailed photographic documentation was made in the limited sections where the angle value between the scanner and the surface to be scanned is low. Photographic documentation is used as an aid to supplement laser scanner data.

Figure 3. a) Leica ScanStation C10 b) Sokkia Set 530RK

The ruins of the south facade of the Mardin Castle, building remains, the rocky formation on the southern slope, the upper part of the castle and the relations of these ruins with the old city settlement of Mardin and its immediate surroundings were photographed in detail with the method of photographic documentation. During these studies, 2 cameras and tripod legs were used. The first one is Fuji Brand FinePix HS10 model, professional digital camera with 30X optical zoom, panoramic shooting, 10.3 mega pixel resolution. The other is an Olympus SP-550UZ, 7.1 megapixel semi-professional digital camera with 18X optical zoom. Photographs were taken from many different points of view of the building from different angles in order to document all parts of the building in detail and completely. The building components are documented, both in general and in detail.

The entire length of the building is approximately 850 m when viewed from the south side at a right angle. For this reason, it was not possible to fit the building into a single photographic frame. For this reason, panoramic photographs of the building were taken from the old city center of Mardin, and the entire facade was tried to be photographically documented. The photographs obtained from these shots show both the stone elements, joints, etc. on the facade and plan plane of the building. evaluated by using laser scanner data in the documentation of building components. In particular,

photographs were taken from the southern façade of the building, from the dominant points of the slope, from the ruins of the castle above the castle, from places such as caves and vaulted galleries. In covered spaces, all the walls, floor and top cover etc. Numerous and detailed photographic documentation has been made from suitable positions to describe its components. In addition, the rock formations on the southern slope were photographed in detail in order to document the rock formations in detail.

In order to use photographs in drawings; Photogrammetric study was carried out by using photo correction method with Photoshop CS4, PhotoPlan 5.0.1.9, and Archicad 6.3 programs. Photogrammetry method and laser scanner data were used together, especially in the drawings of the building sections where the laser scanner data is insufficient and technically impossible to document by the laser scanner. These programs, which are used with the photogrammetry method, can correct the optical deformations caused by the camera as well as the measurement changes caused by the depth (Alptekin et al., 2019; Kabadayı & Uysal, 2019; Karabacak & Yakar, 2022; Karataş et al.,2022; Kaya et al., 2021; Şenol et al., 2017; Şenol et al., 2020; Ulvi & Yiğit, 2022; Ulvi et al., 2015).

2.2. Processing of Data

Major licensed software used with the Leica ScanStation C10 laser scanner; Leica Cyclone 7.1. with Leica Cloudworx 4.1.2. are programs. The laser scanner performed scanning with the Cyclone Scan module integrated in the device. By using the Cyclone ViewerPro module, scanning data could be followed in 3D from the screen on the device or the portable computer screen connected to the device during field work.

Using the Cyclone Model Space module, excess or unnecessary scans (environmental factors that entered the scan outside the main structure) were cleaned from the raw data transferred to the computer to be processed.

By adjusting the coordinates of the drawings, the scan data has been transformed into an easily operable form. The data of different stations, which were made ready to be processed with the Cyclone Model Space module, were automatically combined by the software according to the stations and reference points using the Cyclone Register module. At this stage, the station data, which cannot be combined for any reason, can also be

combined with the total station device, using the coordinate map of the reference points obtained simultaneously with the laser scanner in the field, integrated with the Cyclone Register module. The location, sequence, dates, etc. of the stations that were recorded in the field book during the station combinations. Notes were also used for control and providing purposes.

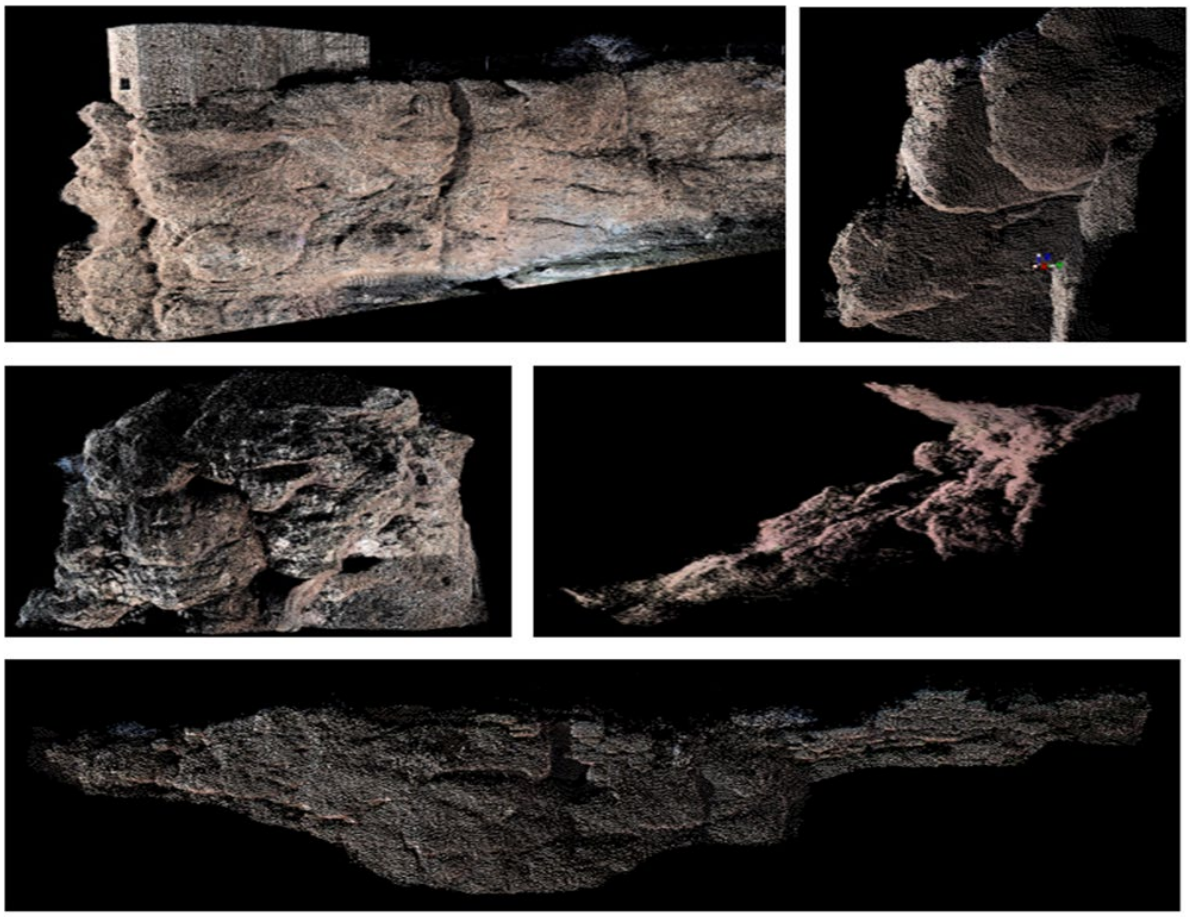


Figure 4. Examples of 3D point cloud images obtained by scanning the castle with a laser scanner (Mardin Metropolitan Municipality, 2023)

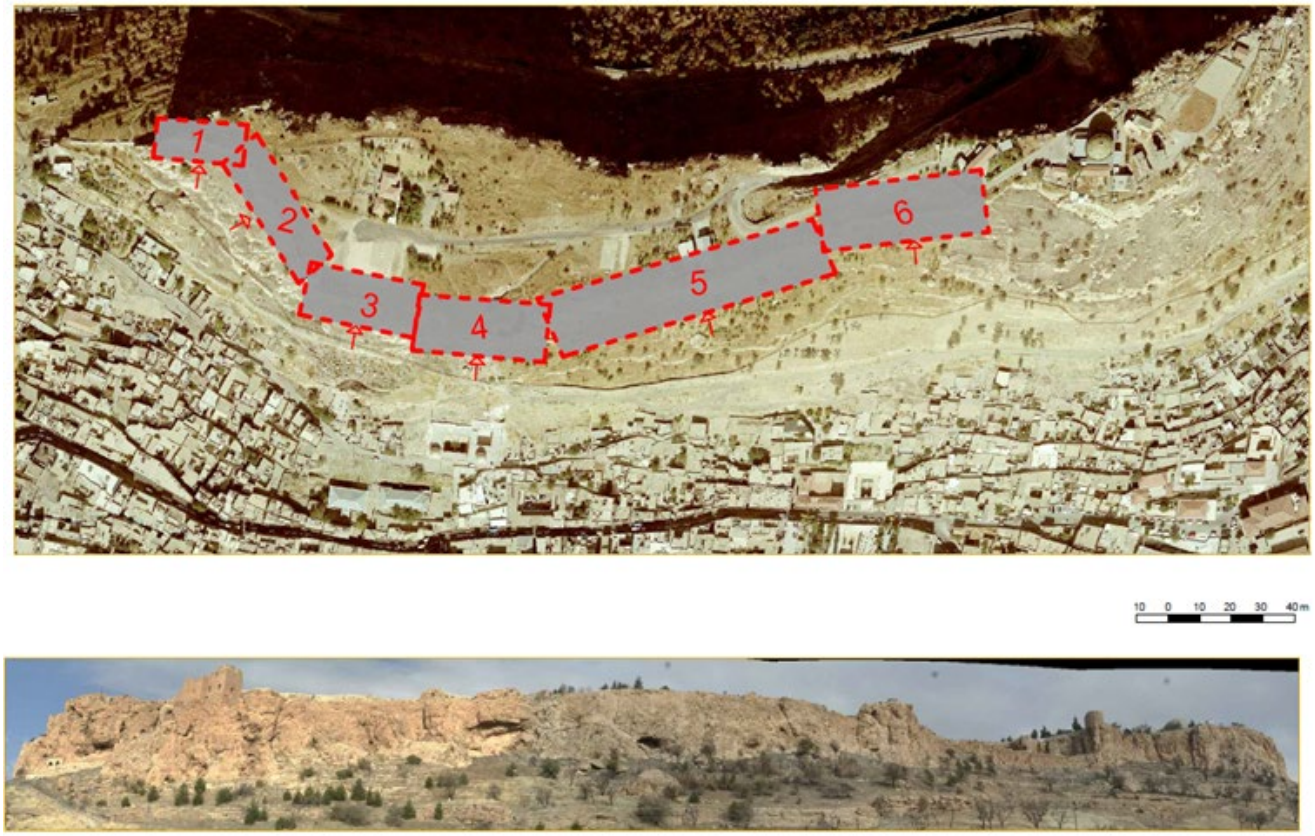


Figure 5. Layout plan (Key Plan) showing the drawing directions of Mardin Castle (Mardin Metropolitan Municipality, 2023)

The scan data prepared with the Cyclone software and its sub-modules are sent to the B.D.T.P. (Computer Aided Design Program) has been made viewable so that drawing can be made on it. At this stage, B.D.T.P. General and detailed drawings of the structure were made through the point clouds of the main structure opened in the environment (Figure 4). By using the 3D point cloud that can be viewed with the Cloudworx software, a facade or detail image can be taken on the desired axis on the building. B.D.T. Facade drawings of the building were made using software programs.

Ortho-images were obtained with Cyclone software, especially for the drawings of the southern cliff rock blocks, masonry texture, profiles, and knitting joints. The detailed drawings of the building and the individual drawings of the rock blocks could be made through the orthographic photographs obtained at a one-to-one scale. Orthographic photographs have the feature o being colorless or in the original colors of the object. The detail drawings of the rock blocks were made using orthographic photographs (in tif format). In order to obtain these ortho-photos used in the drawings, a right angle viewpoint was determined across each rock block and view drawings were obtained with a perpendicular viewpoint. The drawings of the rock blocks were prepared on these ortho-photos and they were made into a map.

In the drawings of the plans and façades, the lower level of the keystone of the arch on the western side of the mass, which consists of two arched structures at the top of the stairs leading to the castle and located near the lower western part of the cliffs, is defined as ±0.00 m elevation in the project. The other levels of the building were calculated with reference to this level and were processed in the drawings. Stone, ornament etc. measured by hand or laser distometer. The detail drawings of the elements were reflected to the drawings with their exact measurements. With the standard coatings, changes and deteriorations are expressed with the scanning command and graphic presentation techniques. For architectural elements, the drawingsmade on paper with a profile comb were scanned with the HP brand Photosmart C3180 scanner, and then the B.D.T. program and adapted to the required scale by drawing on it. The building sections that were measured with the total station were measured with the help of TachyCAD 5.0.0 program on laptop computers connected to the total station device. The rough drawings of the measured sections were created in the field, by controlling the measured points on-site and simultaneously. After the rough drawings were created during the land measurements using the TachyCAD 5.0.0 plugin, the measured drawings were prepared with personal computers using computer aided design programs. The excess lines formed in the rough drawings made in the area were deleted, and the manual measurements and drawings of the architectural elements were added. Drawings are rearranged in a layer system where pen thicknesses are adjusted.

The castle fortification is basically a masonry structure that continues in the east-west direction, with different amounts of remains and directions. In addition, the fortification wall structure creates very different angles in the east-west foundation direction. In this

framework, it was not possible to transfer the castle wall structure to the architectural drawing with a single point of view to be determined. For this reason, 6 viewing directions have been determined, where the castle wall can be seen in as large parts as possible with a right angle. With these points of view, the photographs of the castle walls were converted into drawings by looking at them. The remains of the walls, which, although viewed from 6 viewing directions, are perpendicular to these directions of view or at angles that would not be suitable for drawing details, were drawn by looking at the wall remains from the determined cross-section points. Existing in the upper structure of the fortress, the military-purposed interior and its annexes, vehicle roads, paths, helipad, cistern, etc. units were tried to be expressed in the details required by the possible scale on the facades with the site plan and plans (Figure 5).

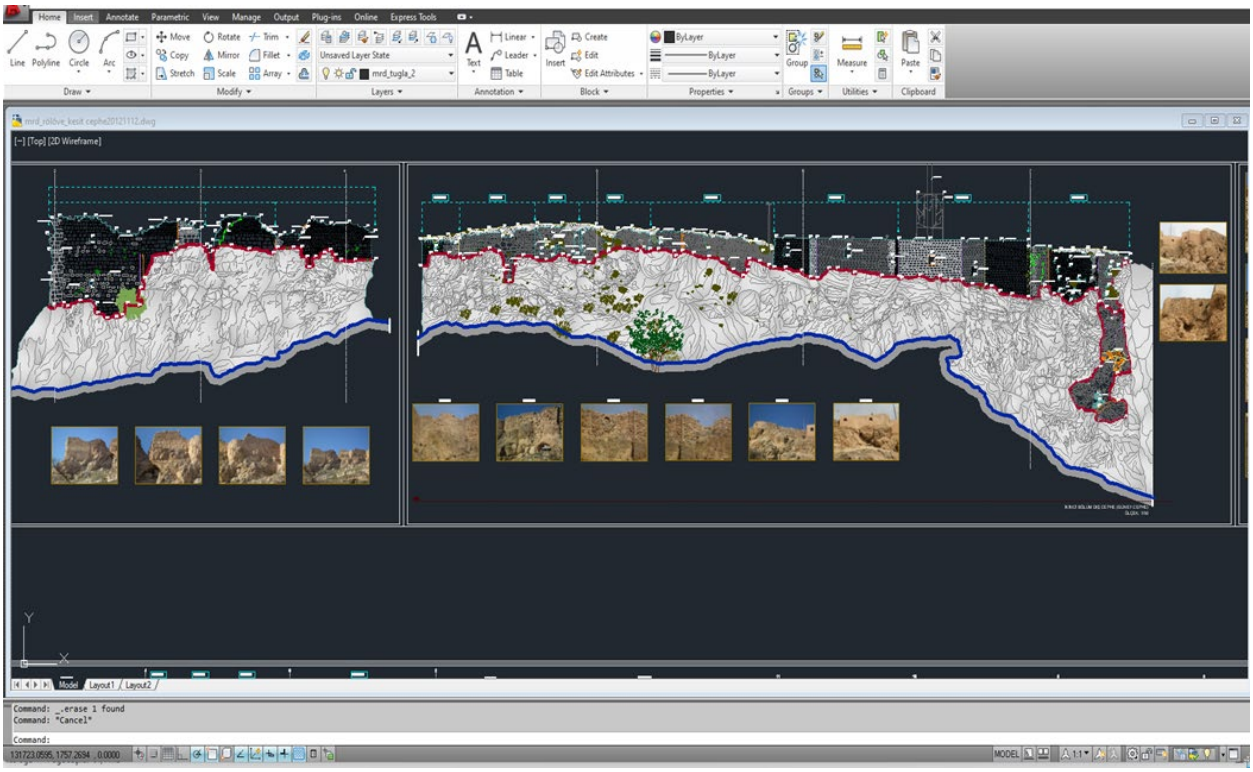


Figure 6. Visual example from photogrammetric documentation made in Autocad (Mardin Metropolitan Municipality, 2023).

3. Findings

Within the scope of the study, 6 points of view from which the castle wall can be seen in as large parts as possible at right angles have been determined, and these aspects have been transformed into architectural drawings. The image given below is a diagram that explains what the colors specified in architectural drawings mean. All architectural drawings are interpreted according to the colors defined in this legend (Figure 6).

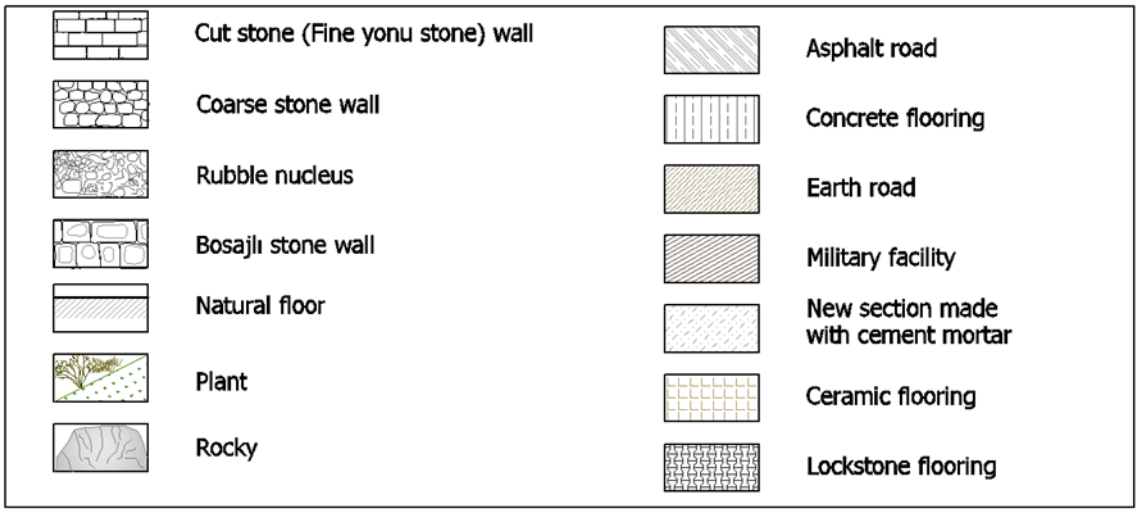


Figure 7. The defined chart of the facade surveys

3.1. First Part Facade

Surveys In the part that corresponds to the first section of the castle, at the western end of the wall line and extending in the south-north direction, the rough cut stone masonry is seen with a bossage at the bottom and five rows on the top. In the continuation of the wall in question extending to the north, breaks are made in accordance with the rock formations. At the bottom, there is a fragment of rough-cut stone masonry, in which regular cut stone blocks are used from time to time. At the top there is a rough-hewn masonry consisting of rows of smaller stones (Figure 8).

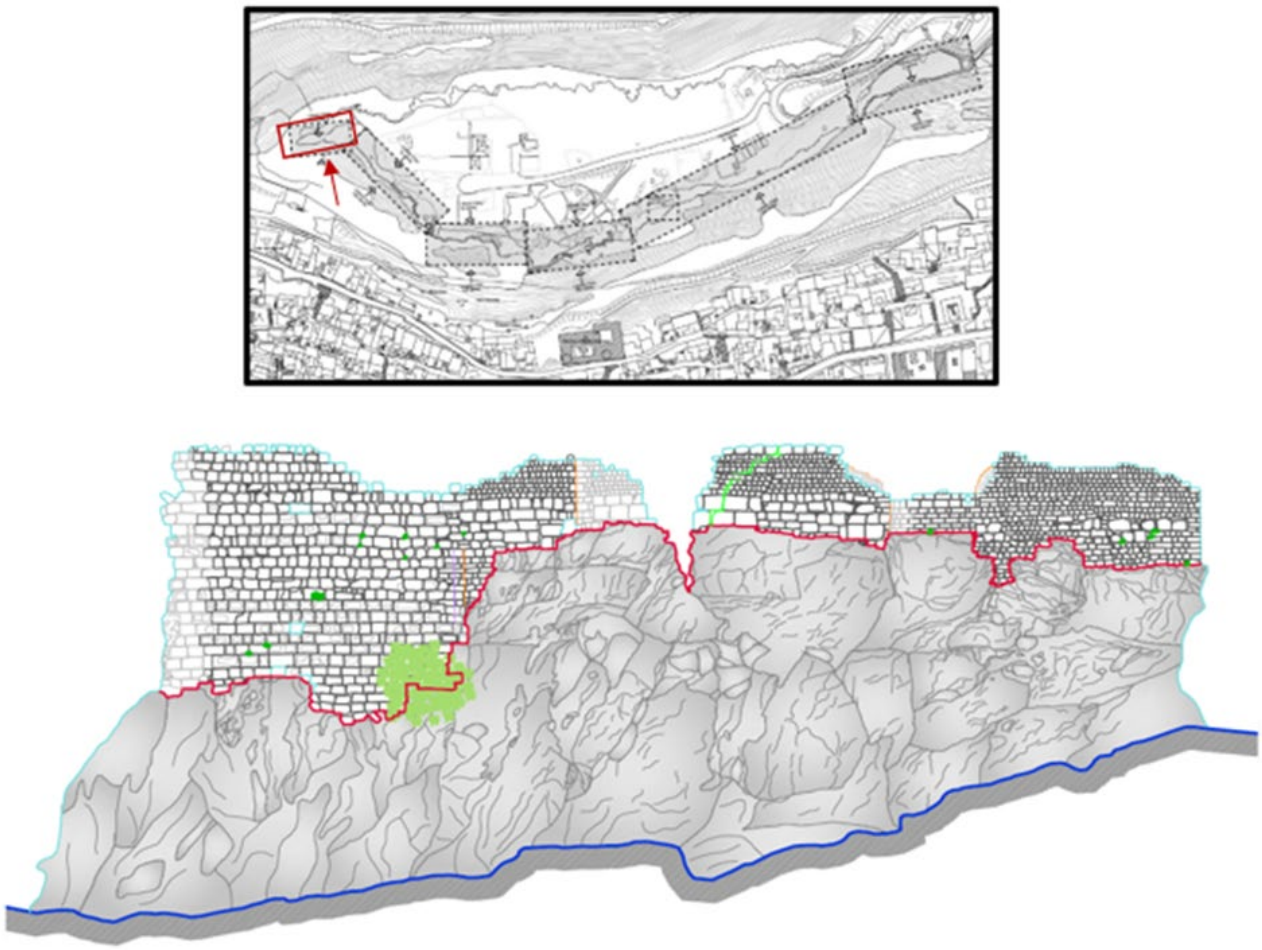


Figure 8. Analytical drawing expressing the south façade view of the first part of the castle (Mardin Metropolitan Municipality, 2023)

3.2. Second Part Facade Surveys

The part of the wall (section 2), which starts from the northern corner and extends to the east with a right-angle break, contains some details that give information about its original condition, although it has been largely destroyed over time. In this context, there is no doubt that the semi-circular shaped ashlar remains in the north corner of the city wall, where it made a right-angle break and which was later added to the wall extending in the south-north direction, belonged to a tower that was once placed in this corner. In the continuation of the wall line extending towards the east, the semi-circular remains of regular cut stone masonry, which apparently were later articulated, on the middle part of the wall resting on the rock formation protruding towards the south, and an in-situ circular slot on the south-facing façade are seen (Figure 9).

3.3. Third section facade surveys

After this point, it can be observed that the wall line extends towards the east by making various breaks in the form of a coarse stone masonry wall following the existing rock formations. However, the upper parts of the wall were raised as a result of major repairs, which were understood to have been made recently, and lost their original state (Figure 10).

3.4. Fourth section facade surveys

Today, it can be said that the building, which is located at the end of the third section and consists of a ruin, served as a bastion with a rectangular plan, protecting the gate no. The part of the wall that extends to the east by passing the İçkale gate from the top, makes a right-angle turn as a wall of neat cut stone, following the rock that extends to the south by making a nose at this point, and breaks again at the point where the rock

ends and extends towards the east as a monumental facade design. It is noteworthy that the wall in question turned into a qibla façade of a 14-15th century religious and social structure, also known as the Kale Mosque, located in this part of İçkale (Figure 11).

3.5. Fifth section facade surveys

The part of the wall, which broke to the north following the qibla wall of the Kale Mosque, turned to the east again on the rock formations in this section and extended in various fractures, although it was largely destroyed, with its coarse stone masonry, it is a part of the Artuqid Age (2nd Period). describes the product. Although it is understood that the vertical rectangular window openings with hewn stone frames, which can be seen in the middle sections of the wall in question, are related to the internally articulated structures at this point of the wall, it is not possible to determine their functions today as they are completely underground (Figure 12).

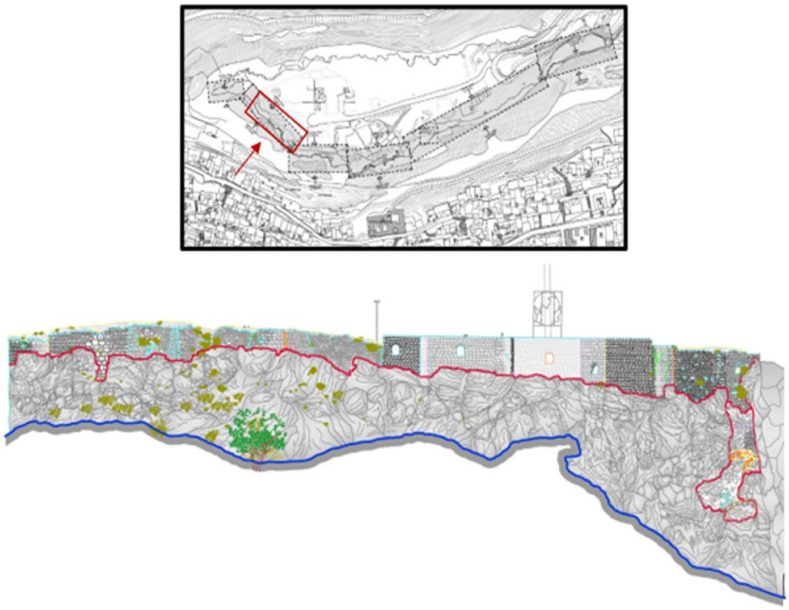


Figure 9. Analytical drawing expressing the south façade view of the second part of the castle (Mardin Metropolitan Municipality, 2023)

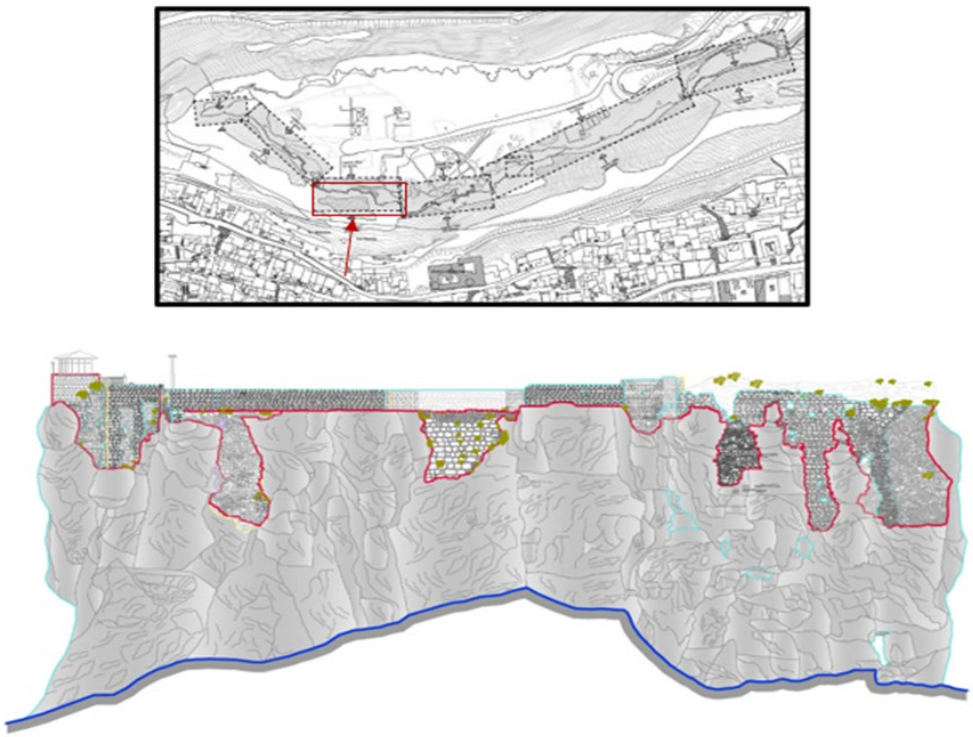


Figure 10. Analytical drawing expressing the southern facade of the third part of the castle (Mardin Metropolitan Municipality, 2023)

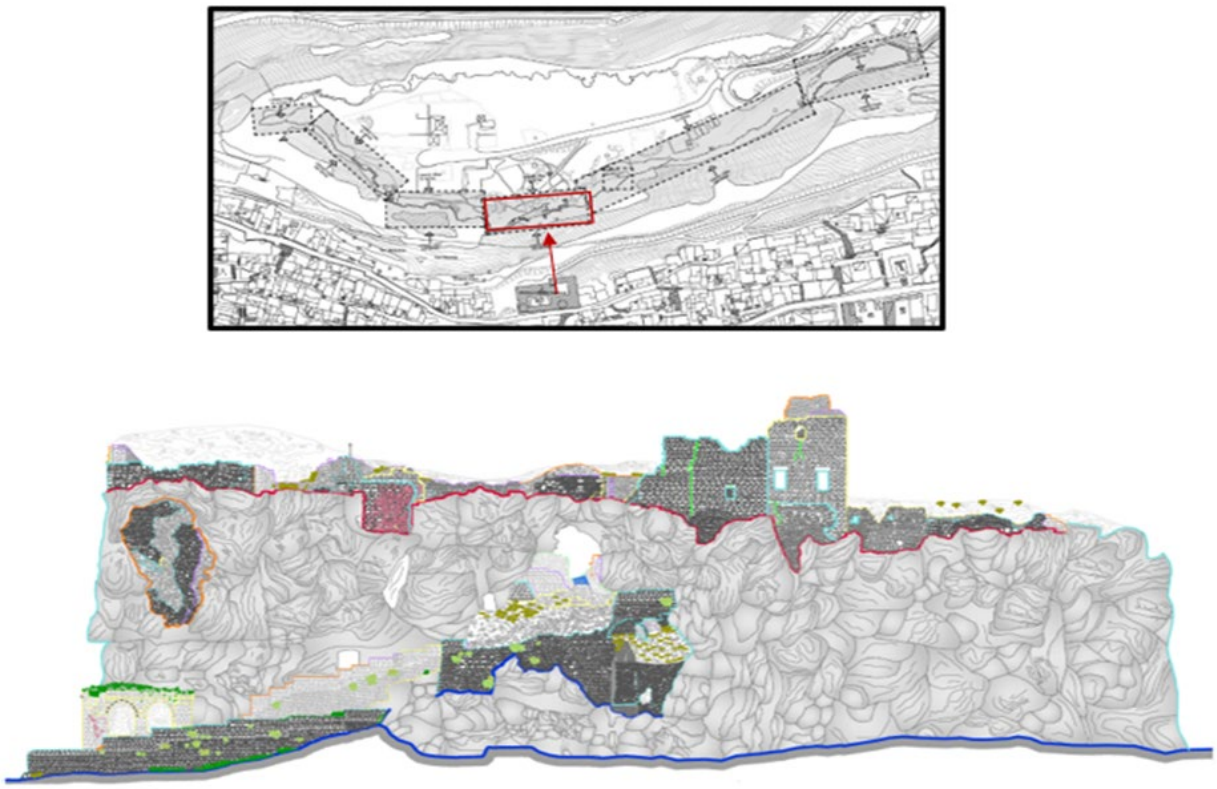


Figure 11. Analytical drawing expressing the southern facade of the fourth section of the castle (Mardin Metropolitan Municipality, 2023)

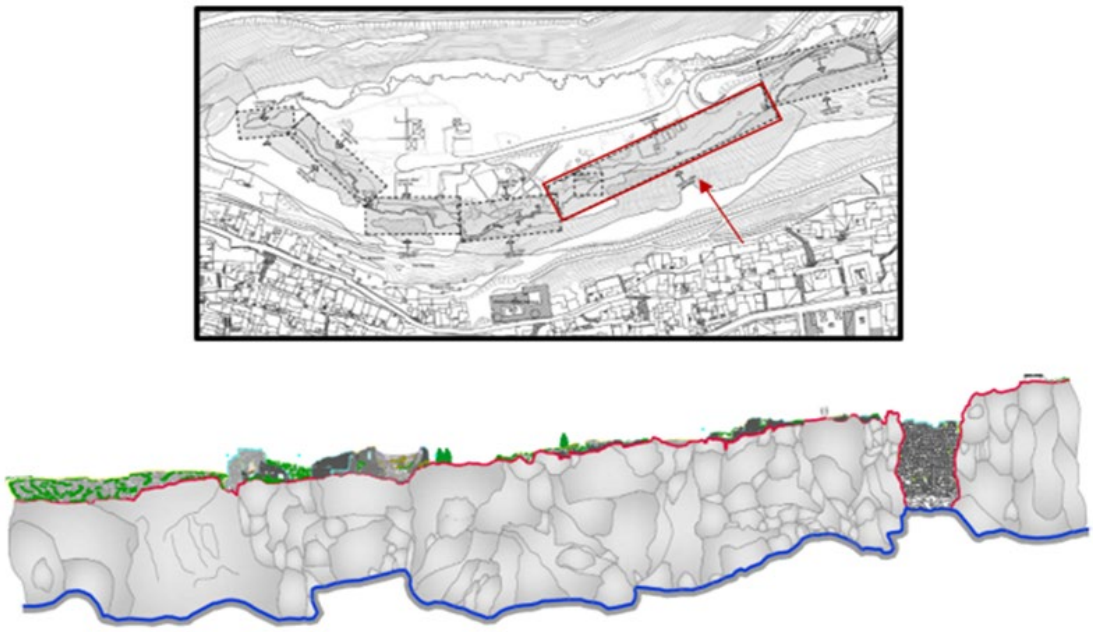


Figure 12. Analytical drawing expressing the southern facade of the fifth section of the castle (Mardin Metropolitan Municipality, 2023)

6. Sixth section facade surveys

The walls forming the next part of the wall have almost completely disappeared and can only be partially traced as foundation walls on the west wing. It can be accepted that the block with smooth cut stone pavement in this section is a product of the Ottoman era in order to reinforce the destroyed places. On the other hand, there are rough-cut stone masonry wall extending in a continuous line between the two ends of the rock formations forming a crescent-shaped recess in this section, and remains at the western end of the wall, possibly belonging to a square bastion. It is understood that the wall behind the wall line and on which imitation dendans were added was added recently (Figure 13).

Figure 13. Analytical drawing expressing the southern facade of the sixth section of the castle (Mardin Metropolitan Municipality, 2023)

4. Discussion

The main purpose of this article is to document the ruins of the southern facade of the Mardin castle and the rocky cliffs with architectural drawings. For this purpose, it has combined different analytical and investigation techniques such as terrestrial laser scanning, photogrammetry and observational analysis.

In the study findings, facade surveys of the facade of the castle were obtained. Thanks to the point clouds obtained from laser scanning in the study, the data that will be the base for the facade, plan and section drawings required for the relief plans can be obtained through the images that can be created with various software. In the study, analytical reliefs obtained from the point clouds obtained by the laser scanning method could be easily obtained. et al., 2010;Comert et al.,2012; Gabriele et al., 2010).

In addition, the desired data could be created in a very short time with the presented method. It has been observed that the use of laser scanning method instead of traditional methods in documentation studies reduces the time needed for field studies by 75% and the time needed for drawing operations by 25%. The results of the study confirm the studies in the literature, which argue that methods such as terrestrial laser scanning technology save a great deal of time and effort in the documentation of huge structures such as castles (Alptekin & Yakar; 2021; Jo & Hong,2019; Yakar et al.,2010;2014; Yakar ,2015; Kanun et al.,2021; Larsson et al.,2006; Pane et al.,2020; Schulz & Ingesand,2004; Ulvi & Yakar, 2014; Yakar et al.2015; Yiğit & Uysal,2019;Karataş & Menteşe, 2022; Yilmaz et al. 2008; Yilmaz & Yakar, 2006; Lerones et al., 2010).

5. Conclusion

The preservation and development of ruined castles and fortresses in historical cities represents a great challenge in the field of cultural heritage today. In-depth knowledge of buildings with a multidisciplinary approach constitutes an inevitable task for any harmonious reuse project of this type of property. In the case of Mardin castle, an effective combination of all the most advanced methods for digital research of architecture, such as photogrammetry and laser scanning, was tested. These techniques will express their maximum potential when they intersect with historical analysis, static analysis, and other direct and indirect research methods of the fortress. It is suggested that the historical castle can be included in a continuous maintenance monitoring process in future studies. By using the data we obtained as a base, all 3D data, drawings, historical analyzes etc. Establishing a holistic tracking system for the building by embedding it in the HBIM environment is important for the protection of the building.

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I would like to thank the Mardin Metropolitan Municipality for sharing the terrestrial laser scanning data and images of the Mardin Castle with me.

Author contributions

The work has a single author.

Conflicts of interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

Research and publication ethics were complied with in the study.

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