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Araştırma Makalesi / Research Article

Investigating the Material Deteriorations on the Facades of Stone Structures by Terrestrial Laser Scanning Method: Case Study of Mardin Mansion

Lale KARATAŞ[1*], Aydın ALPTEKİN[2], Murat YAKAR[3]

[1]*Department of Architecture and Urban Planning, Mardin Vocational School, Mardin Artuklu University, Mardin, Turkey*

[2]*Department of Geological Engineering, Faculty of Engineering, Mersin University, Mersin, Turkey*

[3]*Department of Geomatics Engineering, Faculty of Engineering, Mersin University, Mersin, Turkey*

e-mail : aydinalptekin@mersin.edu.tr *ORCID ID: https://orcid.org/0000-0002-5605-0758*

e-mail : myakar@mersin.edu.tr *ORCID ID: https://orcid.org/ 0000-0002-2664-6251*

Corresponding author e-mail: lalekaratas@artuklu.edu.tr* *ORCID ID: https://orcid.org/ 0000-0001-8582-4612*

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Terrestrial laser scanning; Orhtophoto; Deterioration; Stone material; Cultural Heritage

Abstract

Mardin Mansion is located in the protected area of the Mardin urban site. The building is a valuable building that reflects the architectural features of the traditional houses of Mardin. The aim of the study is to investigate the stone material problems of the historical Mardin mansion, which reflects the traditional housing characteristics of the province of Mardin. For this purpose, the data obtained from observational and laser scanning were combined and interpreted. As a result of the study, the most common types of material deterioration in buildings; It has been seen that there are dıscolouratıon and plants. It is thought that the intense discolouration occurring on the facades is due to the effect of increasing air pollution in the region. As a result, it is recommended to take precautions against the damages caused by air pollution on the facades of the buildings in the region.

Taş yapıların cephelerindeki malzeme bozulmalarının yersel lazer tarama yöntemiyle araştırılması: Mardin Konağı Örneği

Anahtar Kelimeler
Yersel lazer tarama; Ortofoto; Bozulma; Taş malzeme; Kültürel miras

Öz

Mardin Köşkü, Mardin kentsel sit alanındaki koruma altına alınmış bölgede yer almaktadır. Yapı Mardin geleneksel evlerinin yöreye mimari özelliklerini yansıtan değerli bir yapıdır. Geleneksel konakta, çeşitli etkenlerden dolayı oluşan bozulmalar açıkça görülmektedir. Çalışmanın amacı, Mardin ili geleneksel konut özelliklerini yansıtan tarihi Mardin konağının taş malzeme sorunlarının araştırılmasıdır. Bu amaçla gözlemsel ve lazer taramadan elde edilen veriler birleştirilerek yorumlanmıştır. Çalışma sonucunda yapılarda en sık görülen malzeme bozulması türlerinin; yüzey kirliliği ve bitkilenme olduğu görülmüştür. Cephelerde meydana gelen yoğun yüzey kirliliğinin, yörede artan hava kirliliğinin etkisinden kaynaklandığı düşünülmektedir. Sonuçta, bölgedeki yapıların cephelerinde hava kirliliğinin neden olduğu hasarlara karşı önlem alınması önerilmektedir.

1. Introduction

The preservation of the physical integrity of the buildings is also important for the sustainability of the traditional architectural culture prevailing in that geographical context (Riegert and Turkington 2003). Stone structures are subject to physical deterioration as a result of various factors (Karataş *et al.* 2022, Alptekin *et al.* 2019, Kanun *et al.* 2022). These deteriorations in the structures occur with the effect of various factors and processes (Karataş

2023). It is of great importance in terms of determining and understanding these factors and processes correctly and applying appropriate protection interventions (Martinho *et al.* 2014, Kapsalas *et al.* 2007).

When the relevant literature is reviewed, it is seen that there are numerous factors affecting the stone material deteriorations in the world. Factors such as the hours of sunshine on the structure due to the location of the structure and the wetness – drying process affecting the stone are among the most significant factors affecting the deterioration of stone structures in the world (Robinson and Williams 1996, Paradise 1999, O'Brien *et al.* 1992). Fioretti *et al.* 2018, states that the material deteriorations, which are dominant on the stone structures, differ between the locations on the facades of the structure and hours of sunshine and weather data during exposure must be investigated in order to interpret the deterioration rates. Another major factor, which causes stone material deterioration, is the humidity content and saline affecting the stone. The presence of humidity and saline solution remaining for a long term within the porous environments of the stone materials provides the environment required by various deterioration types and intensify the segregation processes (Martinho *et al.* 2014). It is seen that deteriorations called as plant formation on the stone material with the impact of the water and saline within the solution occur more, since the porosity is higher, particularly in the countries, where limestone constructions are high, such as in South Italy (Fioretti *et al.* 2018).

In the literatüre stated that the deteriorations types seen as black crust on the stone structures are also increasing (Graue *et al.* 2013, Corvo *et al.* 2010, Moroni *et al.* 2004, Spezzano 2021). Main component of the black crust, which are observed on the areas of the monuments that are protected by rain, is caused by sulfur dioxide (SO2) (Moroni *et al.* 2004). Formation of black crust appear as decolorization and a dıscolouratıon varying from reddish-brown to brown-black depending on the exposure of the lower layer and chemical composition (Kapsalas 2007).

Stone material deteriorations may be caused by different reasons due to the changing environmental conditions. Within this context, it is emphasized in the literature that there is an increasing need to research which strategies may be appropriate to manage the material deterioration processes on stone cultural heritage structures, to understand which factors trigger the deterioration processes, and retard their start (Smith *et al.* 2008, Brimblecombe and Grossi 2005, Smith and Prikryl 2007). Assessing the mechanisms, which play a role in stone deterioration, and measuring the scope and severity of stone deterioration processes is crucial to conserve the stone cultural heritage and ensuring their sustainability (Cammarano and Tian 2018). In addition, it is also highlighted in the literature that the traditional methods are insufficient to analyze the material deterioration better, and the advantages of combining terrestrial laser scanning with the other software tools De Reu *et al.* 2013. De Reu *et al.* 2013, demonstrated that 3D modelling of Rome has been created easily within a shorter period and the material deteriorations have been determined easily, by using digital data created with the air images that are enriched by laser scanning and photogrammetry. In the study conducted by Guidi *et al.* 2009, the interventions necessary to conserve, repair and renew the stone material of the church have been demonstrated on the facade drawings by the investigations conducted with laser scanning, in order to determine the material deteriorations of Mathias Church.

It is proven with the studies conducted that there is an increasing acceleration in material deteriorations occurring on the stone structures, which constitute the majority of or cultural heritage, and it is seen that the researches aiming to solve this problem are being intensified recently. It is emphasized that today different disciplines must work together aiming to solve this complex problem, in order to understand the material deterioration processes better, and to make accurate determinations. It is proven with various studies that more accurate results can be determined in a short period with the use of various technologies such as UAV photogrammetry and terrestrial laser scanning, in

order to determine material problems easily and within a short period. However, researches and additional researches, which shall be conducted to determine the material deteriorations within different geographic contexts, are needed, since the factors and processes affecting the stone materials differ in each geographic context (O'Brien 1992, Alptekin *et al.* 2019).

The scope of the study was determined based on the requirements of investigating the environmental factors, which cause material deterioration of different geographic contexts emphasized in the literature, and of combining the other techniques, which meet today's competencies, in the documentation stage of material deterioration. Traditional Mardin Mansion that is the subject of the study, is a formation, which has unique characteristics and a special importance among the examples of stone civil architecture located in Anatolia, has been formed under the decisiveness of the regional elements such as the topography, material, climate, and the cultural elements in the vicinity, as well as the factors such as Turkish-Islamic family structure. The aim of the study is to investigate the material problems of a historical mansion reflecting the characteristics of the traditional housings in Mardin City, which is a unique geographic area, by utilizing the terrestrial laser scanning method.

The article differs in the context of presenting a method using the dense point cloud data obtained from a laser scanner instead of sparse point clouds, which have been used in previous studies utilizing terrestrial laser scanning technique to identify material issues. In similar studies in the literature, the sparse point cloud used to obtain orthophotos creates various disadvantages in damage detection due to low resolution. In this study, these disadvantages have been overcome by utilizing the high resolution provided by the dense point cloud. The novelty that this study brings to the field is the ability to detect damages more accurately, precisely, and quickly using the high-resolution data obtained from laser scanning.

As a result of the study, it was seen that the most frequent material deterioration types seen on the structure were surface contamination and plant formation. The findings of the study confirm that discolouration on the facades of the stone structures caused by increasing air pollution have also occurred within this geographical context.

1.1. Location and history of research area

Mardin Mansion is located at Şar Neighbourhood, 219 Varan Sokak No:1 affiliated to Mardin Province, Centre Artuklu County (''Fig. 1''). Residence entrances of the building are on Varan Sokak located on the east; and the entrances of the stores are located on the Avenue 1. They constitute a part of the complicated building on Avenue 1.

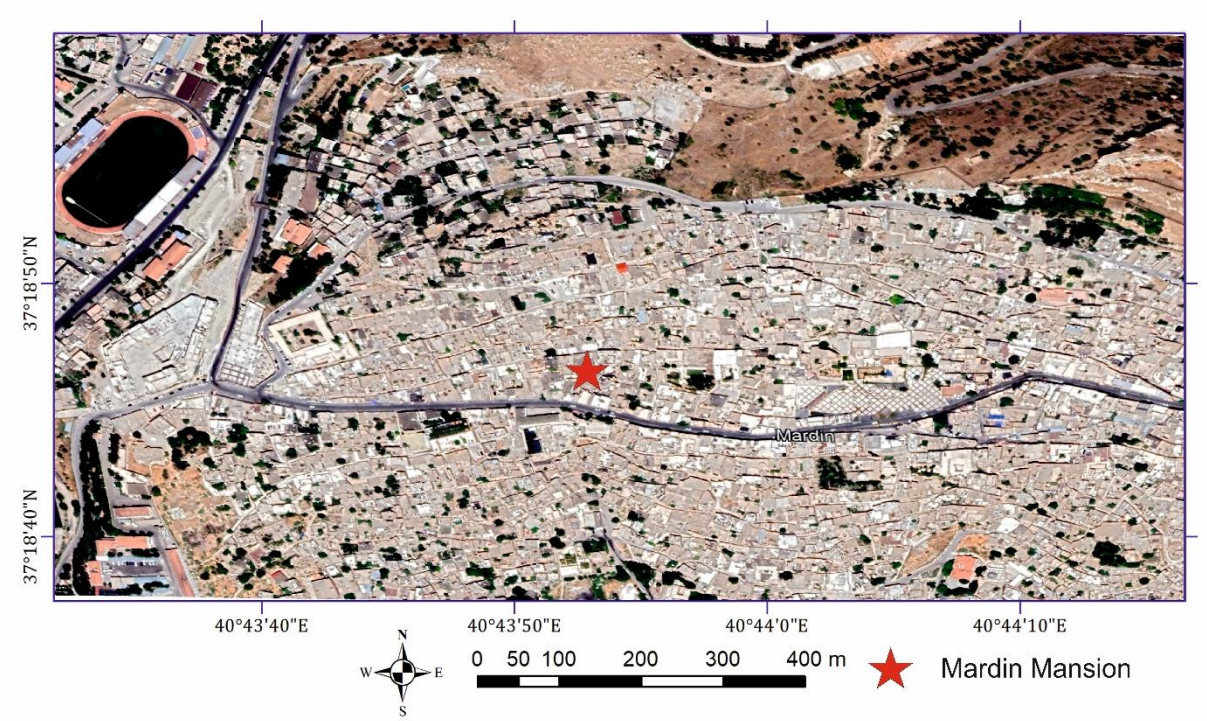
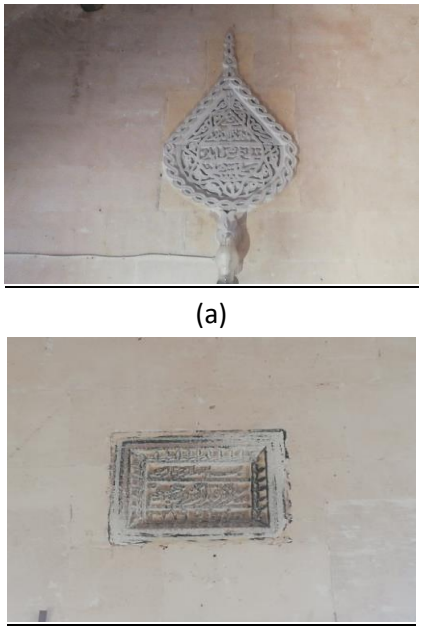


Figure 1. Location map of the study area

A road expansion work between 1950 and 1960 is mentioned in the searches conducted based on verbal data. When the epigraphs of the neighbouring buildings are reviewed, the date of 1958 is seen on the upper floors. There are two epigraphs in the adjacent rooms, which are the continuation of the units, for the history of the building (‘‘Fig. 2’’).

The date of 1881 is read on the 1st epigraph and 1958 is read on the second epigraph, in the dates written by Arabic numbers on the epigraphs. The date of 1958 is seen on the epigraphs of the concrete adjacent buildings, which were constructed new. This detail shows that there was a construction activity in the interval of 1958 (‘‘Fig. 3’’).

Figure 2. Epigraph of 1958 on the adjacent buildings



(a)

(b)

Figure 3. Epigraphs on the building a) Epigraph-1 with drop motive b) Epigraph-2 with flat motive

It is known that the oldest owner of the building was a person named Hacı Hasan –dave-alakuşın the middle of 1980, it was purchased by Pamukçu Family, which is one of the established families in Mardin. In 2019, it was purchased by Filigree Master İbrahim Cihan, who is the owner today. Stores are utilized as filigree sales point and soap sales point, and the upper floors are utilized by an architecture restoration firm, in the current status. The neighbouring units that are the continuance of the building are used by Mr Doğan Ağalday for 12 years: the lower floors are used as stores; upper floors are used as residence and TÜFAD – Turkish Association of Football Coaches, Mardin Branch and ASKF – Federation of Mardin Amateur Sports Clubs.

1.2. Spatial characteristics

Mardin House, which is located in Mardin Province, Artuklu County, Şar Neighbourhood, on block 83 and plot 06, is in a plan scheme that is used frequently among the traditional Mardin houses, with its U plan scheme. The building constitutes the section located on the northeast wing of a complicated house. The building has reached today with road opening works and the construction activities carried out later. The building is consisted of two main floors and two mezzanine floors on Avenue 1. It is consisted of two stores on the facade facing the main road, bathroom on the upper mezzanine floor, two rooms on the second main floor, and mezzanine floor on the top. Balcony is reached from the upper main floor on the south and roof is reached by a stair. Entrance of the stores is on the south, and the entrance of the upper floor is provided on the east from the beginning of the street.

There are two stores facing south on the ground floor. Construction system of the store on the east is reinforced concrete and the construction system of the store on the west is barrel vault. The room, which the entry is provided from the south with a wooden shop window, and which the construction system is barrel vault, is used as the sales point of filigree. When measurements are made in the store, of which its modification was carried out within the scope of simple repairs, it is seen that any furnishing was not made. Woods of the stores have been completed within the process. The niches and candle holders are on the north, east and west facades within the room. Flooring, walls, and the ceilings of the store are stone. It is thought that the room has a connection with the adjacent stores located on the southwest of the room (‘‘Fig. 4’’).

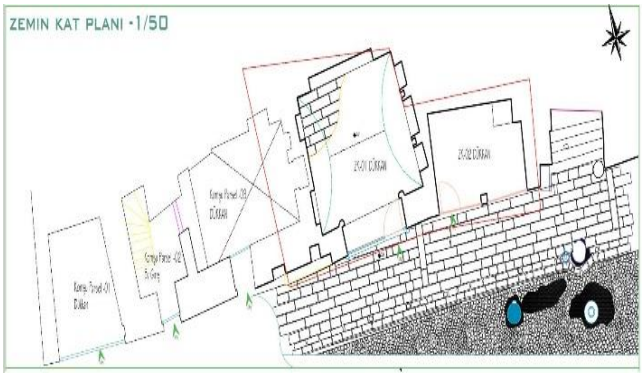


Figure 4. Sketch of ground floor

The stairs, which is accessed via a metal door on the facade of the building facing the east, and the unit utilized as bathroom and WC are located on the first floor (‘‘Fig. 5’’).

Figure 5. Sketch of the 1st floor

Plan of the 2nd Floor: Mezzo hall, waiting room, kitchen, two rooms and the stairs reaching to the upper roof are located in the second floor, which is accessed through the Stairway Landing. Although the base of the construction system involves masonry walls, except the room located on the west, it is reinforced concrete (‘‘Fig. 6’’).

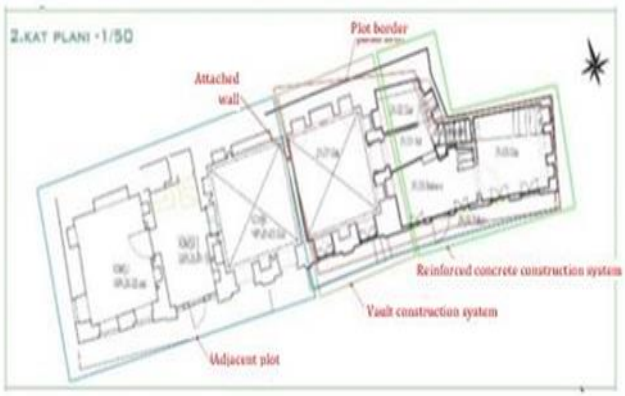


Figure 6. Sketch of 2nd floor

Roof plan: The roof, which is accessed by a metal door from the east, has two stages; the reinforced concrete section, which was constructed later, and the roof section of the vault part. The flooring is concrete screed; the surrounding of the roof is briquette wall and plaster on the north, and there are metal rail guards and two-lines of freestone on the east and south. (‘‘Fig. 7’’).

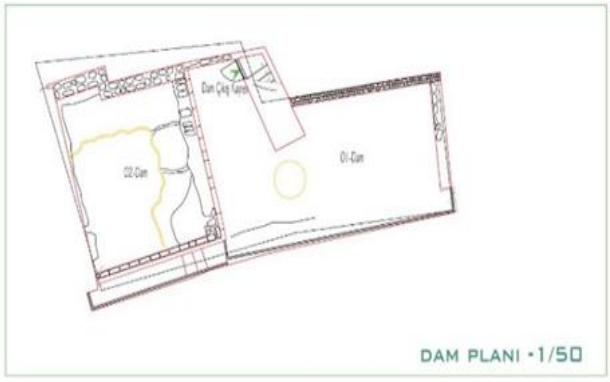


Figure 7. Sketch of roof

The carrier system of the building is groined vault and reinforced concrete. It is thought that the emergence of concrete in Mardin and the expansion works on the Avenue 1 has been efficient on the recent status of this building. When the building facade is assessed together with the neighbouring plots, it is seen as a whole (‘‘Fig. 8’’).

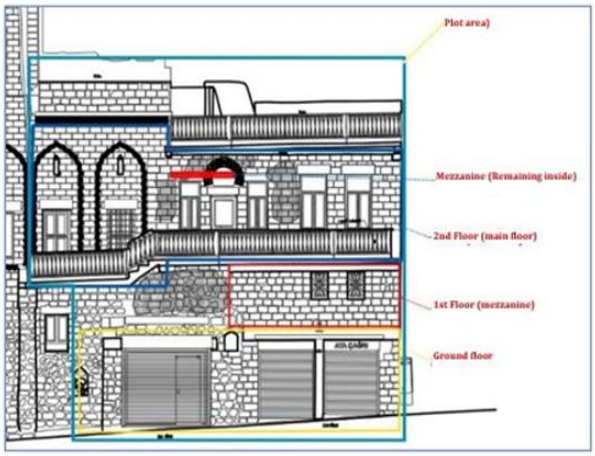


Figure 8. View of the floors of the building

1.3. Facade characteristics

North facade: Rubble, freestone and briquette masonry are seen on the facade, there are facade beams of reinforced concrete attachment, which was made later (‘‘Fig. 9’’).

Figure 9. North façade

South Facade: The south facade faces the main avenue. It is seen that the facade of the room, which is located on the west of the facade, was constructed in the same system with the adjacent building. The facades of two stores on the ground level, two windows of the upper mezzanine floor, balcony and the metal joinery of the building are seen. The building has been subjected to major changes during opening the Avenue 1 (‘‘Fig. 10’’).

Figure 10. South Façade

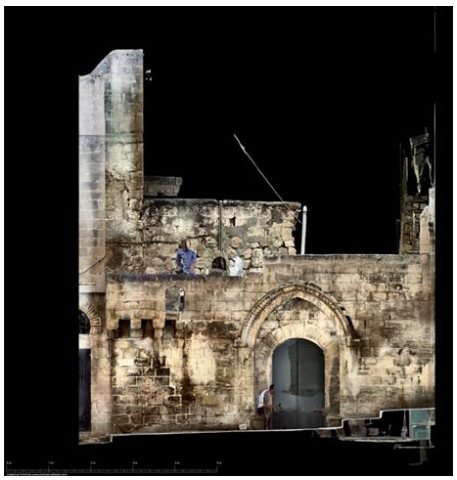
East Facade: Double-wing metal entrance door, concrete beams of it, freestone masonry level and the plastered area are seen on the east facade (‘‘Fig. 11’’).

Figure 11. East Facade

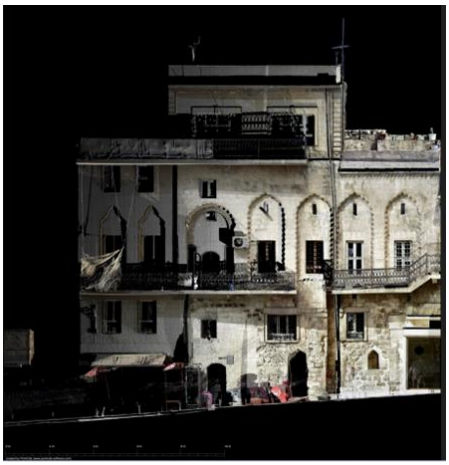
2. Material and Method

Terrestrial laser scanning is frequently used recently in the solution of both engineering and architectural problems (Alptekin *et al.* 2019). Intense and sensitive point cloud, which is obtained from laser scanning, can be taken without contacting with the object and thus the object is not damaged during data collections (Alptekin and Yakar 2020). With laser scanning, millions of coloured points can be obtained as 3D in a short time (Alptekin and Yakar 2020). Laser scanners are used in natural disasters, mining, forestry, in determining the sink-hole area, in determining the deformation of bridge piers, in volume calculations, in modelling of the geological structures, and in relievo studies (Yakar *et al.* 2009, Yılmaz and Yakar 2006).

Measurement and documentation procedures were carried on the housing via terrestrial laser scanning device of Faro Focus 3d X 130 brand. Device was installed on 82 different stations on the area of the building and the building was scanned via Faro Focus 3d laser scanning device and point cloud were obtained. Raw scanning data, which was obtained after the scanning procedures on the area, was combined with the Scene 6.2.03 software, which is produced specifically for Faro Focus 3d laser scanning device. Coloring procedure was carried out by designating color to the point data on each coordinate from the photographs obtained via the integrated camera of the device, after the combining procedure is completed. The point cloud data was converted into a format, which can operate in CAD softwares, by exporting it in .pod and .rcp. Besides, the point cloud, which was obtained by using PointCab 3.3 Software, was transferred to dwg media as 2-dimensional orthophotograph (‘‘Fig. 12’’).



(a)



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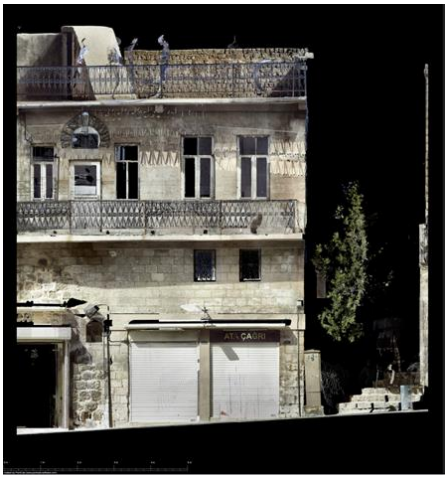

(c)

Figure 12. Orthophotographs obtained regarding the frontages a) Orthophotograph of east frontage b) Orthophotograph of south frontage c) Orthophotograph of north frontage

Panoramic photograph album of each station, where the device was installed, was created by using Pointcab 3.3 programme. Its measured drawings was created in the light of all data obtained, and damage and material determination study were conducted.

3. Results

It is seen that unoriginal stones were used in some venues of the building. Blackening, humidity, swelling and spalling have occurred on vault surfaces, where intervention has been made with plaster, of the building. Building's flooring of the roof was filled with concrete screed afterwards. The legend is provided below regarding the stone material deteriorations occurred on the building (''Fig. 13'').

Figure 13. Legend regarding the stone material deteriorations

Blackening is present on **North facade** (''Fig. 14''). **South facade:** Major changes have been made on the building during opening. Blackening is present on the facade (''Fig. 15''). **East facade:** There are blackening and humidity-originated plant formation present on the facade (''Fig. 16'').

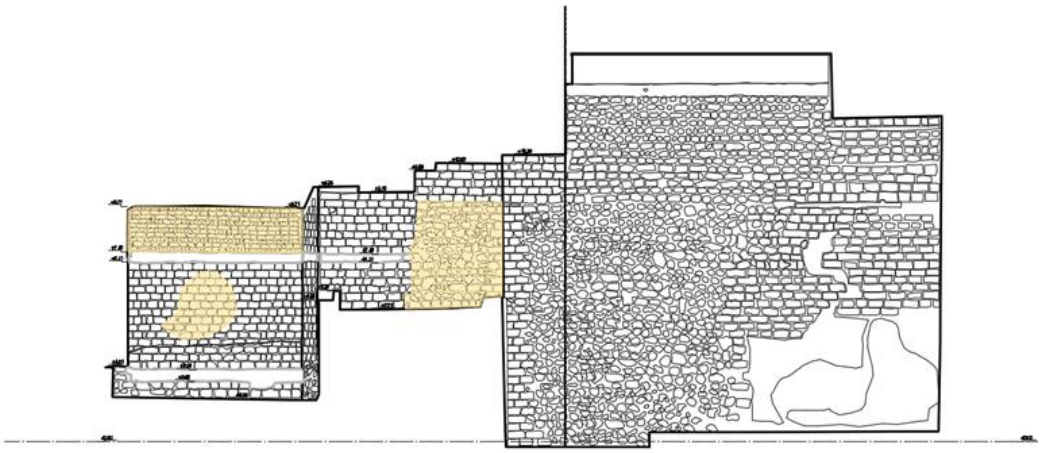

Figure 14. Material deterioration measured drawing of north façade

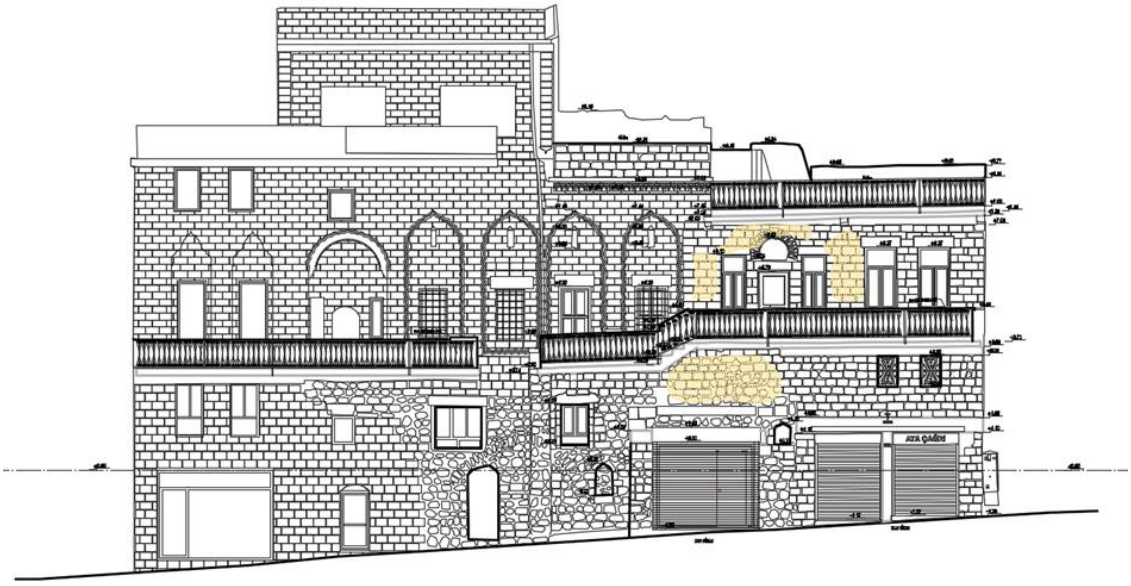

Figure 15. Material deterioration measured drawing of south façade

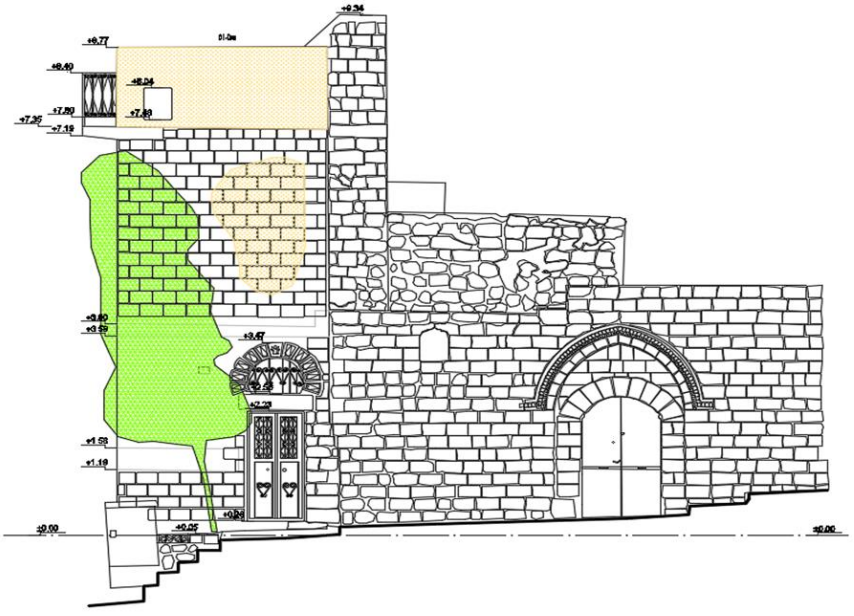

Figure 16. Material deterioration measured drawing of east façade

4. Discussion

The aim of the study is to investigate the material problems and causes of a historical mansion reflecting the characteristics of the traditional housings in Mardin City, which is a unique geographic area, by utilizing the terrestrial laser scanning method. As a result of the study, the first finding that must be emphasized is that the most frequent stone material deterioration type seen on the building is in the form of discolouration as a result of air pollution.

As a result of the observations carried out on the historical building, the excessiveness discolouration on the facades that are caused by the air pollution, due to the fact that the building is located on the avenue called Avenue 1, where the vehicle traffic is the most intense, draws attention. This result support the finding determined in the studies conducted in different studies, regarding that the types of deteriorations seen in the form of discolouration and black crust on the facades of stone structures increase as a result of air pollution, specific to Mardin Province (Karataş *et al.* 2022, Karataş and Alptekin 2022, Karataş,2023).

Another significant finding that must be emphasized is the intensity of plant formation seen on the east facade of the building. The reason of the intensity of this plant formation is the excessiveness of the factors such as wetness – drying process, which affects the stone due to having less hours of sunshine on east facade. This finding confirms the fact that factors such as sunshine hours and the wet-drying process in the building are effective in the deterioration of stone structures in the world (Robinson and Williams 1996, Paradise 1999, Martinho *et al.* 2014, O'Brien 1992, Kapsalas *et al.* 2007). For this reason, in order to interpret the causes of deterioration in the facades correctly, the factors that the facades are exposed to should be investigated specifically for the facade.

As a result of the study, it is seen that material deteriorations can be created easily and in a short time from the data obtained from the terrestrial laser scanning method, and the material deteriorations can be determined easily. This result verifies the results of the study performed by Guidi *et al.* 2009 regarding that the interventions required to renew the stone material can be easily mapped on the facade drawings with laser scanning carried out to determine the material deteriorations. Furthermore, the study supports the results emphasizing that the material deteriorations can easily be determined with the method of terrestrial laser scanning, traditional methods are insufficient today to analyse the material deteriorations better, and the advantages of combining terrestrial laser scanning method with the other software tools (De Reu *et al.* 2013).

5. Conclusion

Within the scope of the study conducted, the material problems and causes of a historical mansion reflecting the characteristics of the traditional housings in Mardin City, which is a unique geographic area, with the help of the terrestrial laser scanning method. As a result of the study, it was seen that the most frequent stone material deterioration type seen on the building was discoloration and plant formation. The results of the study confirm the finding regarding that the discoloration on the facades, which are caused by air pollution on stone structures within different geographic contexts of the world, are high.

Besides, it was revealed as a result of the study that factors such as hours of sunshine and wetness – drying process occurring on the building have impact on the deterioration of stone structures in the world, with the effect of the location of the building, material deteriorations, which are dominant on the stone structures, differ between the locations on the facades of the structure and the factors, which the facades are exposed to, must be investigated in order to interpret the deterioration rates.

In the study, it is recommended to remove the plant formations existing on and surrounding of the building, and to clean the places, where humidity, mould and blackening are seen, with pulp, during

the repair process of the building, within the scope of the deterioration types revealed on the building. With the conservation of cultural heritage of a historical mansion reflecting the characteristics of the traditional housings in Mardin City, which is a unique geographic area, through the repairs and reinforcements to be carried out on the building within this context, not only the protection of the physical integrity of the building, but also the sustainability of the abstract concepts such as cultural experiences and social impacts within that geographical context shall be ensured. The results of the study are significant within the context of determining and understanding these factors and processes accurately, applying the appropriate conservation interventions, knowing the deteriorations that shall occur on the structures in advance and taking measures.

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