Advanced Engineering Science
http://publish.mersin.edu.tr/index.php/ades
e-ISSN 2791-8580

Stone materials decay patterns of historical buildings in the Southeastern Anatolia climate: A case study of Mardin history İzzetpaşa Old Prison

Lale Karataş *[1] Tahir Ateş *[2] Aydın Alptekin [3], Murat Yakar [4]

[1]*Mardin Artuklu University, Department of Architecture and Urban Planning, Mardin, Türkiye, lalekaratas@artuklu.edu.tr*
[2]*Mardin Artuklu University, Department of Construction Technology, Mardin, Türkiye, tahirates21@yahoo.com*
[3]*Mersin University, Faculty of Engineering, Department of Geological Engineering, Mersin, Türkiye, aydinalptekin@mersin.edu.tr*
[4]*Mersin University, Faculty of Engineering, Geomatics Engineering Department, Mersin, Türkiye, myakar@mersin.edu.tr*

Cite this study: Karataş, L., Ateş, T., Alptekin, A., & Yakar, M. (2023). Stone materials decay patterns of historical buildings in the Southeastern Anatolia climate: A case study of Mardin history İzzetpaşa Old Prison. Advanced Engineering Science, 3, 37-45

Keywords
Material Deterioration
Stone Material
Stone Decay
Sustainability
Mardin

Research Article
Received: 11.12.2022
Revised: 10.01.2023
Accepted: 15.01.2023
Published:19.01.2023

Abstract

Due to the fact that the stone material used in historical buildings shows different mineralogical and physical properties in every geography and the materials are located in different climatic and environmental conditions, material problems should be systematically analyzed and diagnosed in a geographical context. The aim of the study is to determine the material problems and deterioration processes of the local limestone in the geographical context by detecting the material deterioration of the Mardin Historical İzzetpaşa Old Prison, which was built with local stone materials and has a symbolic value for the city. The study is important in terms of considering structural elements and material deteriorations in an ontological context and explaining the main deterioration patterns observed on limestone material and the environmental effects affecting the material. In this context, the deterioration of the structure was classified and visualized based on the ICOMOS (Illustrated Glossary) stone deterioration classification. According to the data obtained from results of the study; the most common problem in construction elements occurred with stone materials is the use of cement for repair purposes in almost all construction elements. This shows that the Mardin Historical İzzetpaşa Old Prison building, which is the symbol of the region, was not included in a systematic protection program. In this context, the results of the study show that uncontrolled interventions should be prevented urgently in the context of this geography.

1. Introduction

In the transfer of cultural heritage from the past to the future, in addition to intangible factor such as traditions and languages, the structures that make up the environmental context also play an important role. In this context, preserving the structures that play an important role in the transfer of cultural heritage is important in terms of ensuring the sustainability of cultural heritage [1]. Structures such as churches, palaces and castles, which constitute a large proportion of the world's cultural heritage stock, are made of stone material. Stone material undergoes various deteriorations in the face of the factors it is exposed to over the years [2-5]. Even a stone material that does not show any type of deterioration in its outer layer is analyzed, and most of them undergo a gradual and episodic deterioration. When the stone deterioration reaches the advanced stage, the rehabilitation of the material often becomes difficult, and it reaches the stages that are difficult to return [6-12]. In this context, in order to reduce or prevent this loss of our stone heritage, we must first be able to characterize many of the stones involved, define the deterioration, measure its extent, severity and rate, and thoroughly understand the causes and mechanisms of deterioration [13-15]. Analysis of stone deterioration types is one of the most important

steps in this phase. In this context, the determination of the causes of deterioration allows to predict the possible development of deterioration over time, to monitor and to define prevention events [16].

When the studies on the diagnosis of stone material deterioration in different countries in the world are examined, it is seen that different types of stone deterioration are concentrated in each geographical context. The problem of being able to explain the causes and types of stone material deterioration has been a subject that has been emphasized for years in various studies. The reason for this is that the stone material used locally in historical buildings in every geography shows different mineralogical and physical properties and different types of deterioration are observed in the stone material in different reactions under different climatic and environmental conditions. For example, Rishbeth [17] investigated the environmental factors that lead to stone material deterioration mostly in Cambridge and determined that the material deterioration of the stone structures, especially towards the north, is more evident and the reason for this is the high humidity rate due to the low temperature in the northern parts of the buildings, and therefore these areas are preferred by the seed carriers (birds, ants, etc.). Robinson & Williams [18] states that the most deterioration in stone structures in the British Isles is on the shady north-facing facades of the buildings, and this is due to the long 'wet time' of the stone on the northern facades, as the solutions provide more absorption in the stone. Martinho et al. [19] has studied a Portuguese mausoleum made of limestone with severe weathering types, the northern part of the mausoleum was more humid than the southern part, and the stone strength was lower in humid areas. Paradise [20] has emphasized that although the performance in the structures also depends on the quality of the stone, the stones show different types of deterioration according to different weathering agents. In all these studies, since the stone material is mostly affected by environmental conditions and the types of deterioration depend on these reasons, it is emphasized that studies should be carried out to determine the environmental conditions of the stone material in different geographical areas in the world.

Another factor affecting the stone material deterioration mentioned in various studies; inadequate maintenance, use of inappropriate materials, and inappropriate conservation interventions. Price [21] explained that in many countries, stone structures have suffered various deteriorations as a result of previous uncontrolled restoration attempts, and stone materials have been severely damaged as a result of inadequate maintenance, use of inappropriate materials and conservation interventions. Siegesmund et al. [22] has stated that especially in underdeveloped and developing countries, the mistakes of using inappropriate materials due to faulty repairs are evident, the need for restoration is hindered due to the lack of financial support, and this situation threatens the permanence of some historical buildings to a great extent. Torney et al. [23] has stated that the use of highly incompatible, impermeable and/or highly cementitious materials in the past has been the cause of many problems, particularly with regard to moisture retention.

In addition, recent studies in various different countries; air pollution is defined as one of the most important causes of stone deterioration. Commonly emphasized in these studies is that the limestones, which are the most sensitive to acidic pollution, dissolve the airborne pollutants such as sulfur oxides, nitrogen oxides and carbon dioxide in water, and at this stage they react with calcareous materials, forming an acidic reaction on the stone surface and causing various types of deterioration [24-27].

Doehne & Price [28] has implied that the main factor that causes the most deterioration in stone structures in many countries in the world is water and moisture-related reasons. In the results of the research, it is emphasized that water, which is the biggest factor causing damage to stone material, not only changes the surface morphology of the rock, but also changes its physical and mechanical properties, especially for rocks such as limestone with high porosity.

As explained by the results of various studies in the literature; Material deterioration observed on stone material intensifies differently under different influences in various geographical contexts. In this context, it is a necessity to define the types of deterioration according to the geographical context of the countries. One of the biggest problems encountered in the analysis and diagnosis stage to understand the deterioration mechanisms of stone material is to identify the deterioration in the material without damaging the historical structure. Considering this challenge, experts advocate the principle of minimal intervention and propose alternative non-destructive techniques and classifications to evaluate the mechanical and physical properties and behavior of the stone [29]. It is of great importance to use alternative methodologies that reveal the physical and mechanical characterization of the materials used in the building, as it is not always possible to carry out destructive tests on historical old buildings in many cases [30].

In this context, in order to easily identify material deterioration without damaging the structure, in the dictionary of the International Council of Monuments and Sites – International Stone Scientific Committee (ICOMOS-ISCS) [31]and and Fitzner et al. [32] described various stone deterioration models. There are numerous studies in the literature that describe material deterioration on stone structures in various countries using these stereotyped deterioration types. The result emphasized in these studies is in the ICOMOS dictionary [31] and Fitzner et. al [32] described methodologies are suitable for achieving stated goals; however, these methodologies are incapable of interpreting the situation in complex situations. In such a situation, additional data are needed to support a more consistent diagnosis. Since the internalization of terms and the introduction of new ones is dependent on language and culture, defining the same problems of degradation requires that any national or even

any regional society use different words. Therefore, further studies addressing stone material problems and degradation processes on a geographical basis are needed for the transition from scientific analysis of degradation processes to the professional practice of conservation actions.

Based on the geographical analysis and diagnosis of stone material deteriorations stated in the literature, Mardin Historical İzzetpaşa Old Prison is discussed as a case study in our study. The aim of the study is to systematically exemplify the material problems of the local limestone stone and the detection and expression stages required for interventions in the geographical context, by determining the material deterioration of the Mardin Historical İzzetpaşa Old Prison, which was built with stone material specific to the region and has a symbolic quality for the city. According to the data obtained as a result of the observations made in the examined building; The most common problem in construction elements produced with stone materials is the use of cement for repair purposes in almost all structural elements. This situation shows that the Mardin Historical İzzetpaşa Old Prison building, which is symbolic for the region, has not been put under a systematic protection program. In this context, the results of the study show that uncontrolled interventions should be urgently prevented in the context of this geography.

2. Study Area

2.1. Location and Historical Importance of the Building

İzzet Pasha Police Station Building; It is listed as the Gendarmerie Station Building and Land with the annexes registered in the Mardin Province, Artuklu District, Nur Mahallesi address and registered in the title deed 1400 block 4 parcel with an area of 18,612,42 square meters. The Police Station Building, Çelbira 1st Degree Archaeological Site, remains in the interaction area and was registered and protected as a Class I Cultural Heritage with the decision of Diyarbakır Cultural and Natural Heritage Preservation Regional Board dated 11.07.2008 and numbered 1690 [33]. The area where the Historical İzzet Paşa Police Station Gendarmerie Museum Restoration and Landscaping Project will be implemented is located in a location where concentration is foreseen in terms of urban planning and where important living spaces are planned to be established. In addition, it is an important advantage that it is located in the Çelbira 1st Degree Archaeological Site interaction area (Figure 1).

Figure 1. A view from the Celbira Workshop Area, 1st Degree Archaeological Site

2.2. Spatial Features

Located in the north of the Mardin-Diyarbakır road, the parcel where the Police Station Building is located has a sloping structure and was built on an area higher than the road level. There is the Celbira Workshop area, which was used as a grape workshop of the period, adjacent to the south and southwest of the building. The area where the police station building is located is called Zınnar Valley among the people. The police station building, which was built in the 19th century during the Ottoman period, was also used in the Republican Period with various changes. The Police Station Building was built in the Mardin architectural style using Mardin stone. The building, which was built as a 2-storey building, was designed with a square plan and architectural integrity was provided with a circular bastion. Surveillance was provided by making many small window openings for defensive purposes on the facade of the circular shaped bastion located in the southwest corner of the building. The main entrance of the building is provided through the lintel door from the east entrance. There are stairs in front of the door. On the ground floor, there is the tower section to the left of the entrance and the staircase hall to the right. It is understood from the irrigation canals in the place to the west that this place was used as a barn. There are reinforced concrete plasters on the ceiling and walls of the single-storey space in the south, and there is a stone boat in the space. The first floor is reached by a reinforced concrete straight staircase. Two rooms in the north and west directions and the tower in the south are accessed from the stair hall facing the east façade from the first floor. The floors are reinforced concrete and there are iron consoles on the ceilings. Today, this area has collapsed. The door and window joinery of the building has been removed. In the masonry technique, apart from the limestone and rubble

stones, the bossage masonry technique was also used. In this masonry technique, the visible surfaces of the blocks are slightly convex. There is a two-storey high circular tower on the left of the eastern façade. There is an entrance door reached by four steps in the middle of the façade on the ground floor and a rectangular window on both sides, and three rectangular windows on the first floor. On the ground floor of the north façade, there is a rectangular window on the left. On the right of the west façade, there is a single-storey high annex adjacent to the building. There are six small windows on the ground floor of the main building, two small windows on the outbuildings, and three small windows on the first floor.

3. Material and Method

In the first stage, the general features of the architecture of the historical structure of Mardin İzzetpaşa Old Prison were examined. Thus, it is aimed to analyze the structure more accurately. Secondly, the information and documents obtained from the building were examined, and its current situation was documented with photographs and drawings. As a result of the documentation and field work, the deterioration of the structure and the factors causing the deterioration were determined. In the study, observations of the stone weathering that occurred in the Mardin İzzetpaşa Old Prison building within the borders of Mardin province were made, different types of weathering were identified, photographed and documented. ICOMOS illustrated Glossary stone deterioration classification was used to define the deterioration types in the structure. As a result of the observations, the deteriorations detected in the stone materials used in the building were classified according to the elements of the building. In the last stage, all the information, drawings, photographs and evaluation results of the structure under investigation were converted into text in the classification made as a result of the observational determination of the deterioration of the stone material and the study was concluded. The chart prepared within the scope of the study is a chart related to the detection documentation of stone material deterioration. It is aimed that the chart prepared within the scope of the study can also be used for various masonry structures within the scope of the existing geography (Table 1).

Table 1. Determination and documentation of the problems encountered on the construction elements made of masonry materials in Mardin İzzetpaşa Old Prison [34]

NATURAL STONE CONSTRUCTION ELEMENTS				**Problems encountered on construction elements made of masonry material in Mardin İzzetpaşa Old Prison**																			Faulty Repairs		
				Loss of surface	Fragmentation	Formation of gap/ hole	Pitting	Cracks	Spalling	Foliation	Discharge of jointing	Surface contamination	Shell formation	Efflorescence	Crystallization	Formation of plant	Formation of moss	Corrosion (Rust stain)	Tear	Loss of form	Colour change	Use of cement	Fall of plaster	Other
VERTICAL BEARINGS	**Single Legs**	Leg																						
		Column																						
	Continuous Legs	Wall		**x**	-	-	-	-	-	-	**x**	-	-	**x**	-	-	-	-	-	-	**x**	**x**	-	-
HORIZONTAL BEARINGS	**FLOORINGS**	Flat		-	-	-	-	-	-	-	**x**	-	-	**x**	-	-	-	-	-	-	-	**x**	-	-
		Curvilinear	Vault																					
			Dome																					
STAIRS				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**x**	-	-
WALL OPENINGS	Window	Lintel/jamb		**x**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Sill		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**x**	-	-	-	-	-
	Door	Lintel/jamb		**x**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Sill		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Arch			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AUXILIARY ELEMENTS	Network																							
	Moulding			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**x**	-	-
	Gargoyle																							
	Chimney																							
	Element for passage to the cover																							

4. Results

Problems such as joint discharge, use of cement, color change, loss of surface, loss of fragments, stone material problems were encountered in the building. Research results; It is presented on the basis of structural elements such as vertical structures, horizontal structures, auxiliary elements.

3.1. Problems in Vertical Elements

Vertical elements are examined in two parts as single carriers and continuous carriers. Single carriers are defined as columns, while continuous carriers are defined as walls.

3.1.1. Problems with single structures

Columns and feet from single carriers are not visible in the building.

3.1.2. Problems seen in continual structures

On the south-facing façade of the building; joint discharge, cement use, surface loss and discoloration problems were determined (Figure 2). On the east-facing façade of the building; joint discharge, cement use, surface loss problems were detected (Figure 3).
On the north-facing façade of the building; cement usage, surface loss, joint discharge problems were determined (Figure 4). Stone deterioration on the northern façade of the building is due to joint emptying, loss of surface, and incorrect paint application (Figure 5).

3.2. Problems Seen in Horizontal Structures

It is seen that the upper cover of the building consists of flat flooring (Figure 6). Plant formation problems were encountered in flat laying. On the other hand, there was a wear problem on the floor covering (Figure 7).

3.3. Problems on the stairs

From the first floor of the building, two rooms in the north and west directions and the tower in the south are accessed from the stair hall facing the east façade. Cement usage and abrasion are seen due to faulty repairs on the stairs in the building.

3.4. Problems in the wall cavities

The walls, windows and arches on the wall, which are defined as wall gaps, are used to abrasion on the face of the stone material in the gaps with the arches (Figure 8-9).

Figure 2. Stone deterioration on the south façade of the building
Joint discharge **(a)**, Cement use **(b, c)**,
Surface loss **(d)**, Color change **(e)**

Figure 3. Stone deterioration on the eastern façade of the building
Joint discharge **(a)**, Cement use **(b, c)**,
Surface loss **(d)**

Figure 4. Stone deterioration on the north façade of the building

Cement Usage **(a,c,d)**, Surface Loss **(b)**, Surface Loss **(c)**, Joint Discharge **(e)**

Figure 5. Stone deterioration in the interior of the building

Joint discharge **(a)**, Surface loss **(b)**, Incorrect paint application **(c)**

Figure 6. Joint discharge **(a)**, Color Change **(b)**, Piece Loss **(c)**

Figure 7. Abrasion on the ground floor layer

Figure 8. Abrasion of stone material in door openings

Figure 9. Abrasion of stone material in window cavities

3.5. Problems in Auxiliary Staff

There are no decorations in the building, and the use of cement in the gargoyles from faulty applications has been detected.

5. Discussion

The aim of the study; The aim of the study is to determine the material problems and deterioration processes of the local limestone in the geographical context by determining the material deterioration of the Mardin Historical İzzetpaşa Old Prison, which was built with local stone material and has a symbolic quality for the city. The study is important in terms of addressing the structural elements and material deteriorations in the ontological context and explaining the main deterioration patterns observed on the limestone material in the current geographical context and the environmental processes and mechanisms affecting the material. In the monument selected within the scope of the research and whose main building material is stone; Detection and documentation studies were carried out for materials, types of material deterioration and conservation interventions. According to the data obtained as a result of the observations made in the examined building; The most common problem in building elements produced with stone materials, the use of cement for repair purposes has been encountered in almost all structural elements. This shows that even in the Mardin Historical İzzetpaşa Old Prison building, which is symbolic for the region, human-induced faulty repairs were included and the building was not put under a systematic protection program. In addition, this finding; It is similar to the results of the study, which found that stone structures in many countries in the world suffered from various deteriorations as a result of previous uncontrolled restoration attempts, and that stone materials were severely damaged as a result of inadequate maintenance, use of inappropriate materials and conservation interventions [21-23]. These results reveal that faulty repairs made for protection purposes in stone structures are seen in Turkey's Mardin province as well as in many other countries.

Another important finding obtained; Moisture-related stone material problems are more common on the north, east and west facades of the building compared to the south facade. It has been determined that problems such as surface loss and joint emptying are less common on the south façade of the building than on the other façades. This finding; It shows that the material deterioration of the stone structures, especially towards the north, is more evident. The reason for this is that the buildings exhibit high humidity due to the low temperature in the northern parts, and the long 'wet time' of the stone on the northern facades, resulting in greater absorption of the solutions in the stone. For this reason, it supports the findings of studies in England and Portugal, which determined that these areas are preferred by seed carriers (birds, ants, etc.) [17-20].

Another important finding is; no significant corrosive effect of wind or precipitation was observed on the historical structure examined. However, due to the high humidity and different weather conditions on the northern façade of the building, material deterioration on the northern façade was found to be relatively higher than on the other façades. It is thought that another reason for the excess material problems on the northern façade is due to the following situations. The climate of Mardin is warm and temperate, and Mardin receives much more precipitation in winter than in summer. The average annual temperature of Mardin is 16.8 °C and the annual average precipitation is 432 mm. Therefore, the slopes are devoid of vegetation and some forest is not visible at higher altitudes. For this reason, with the strong wind blowing from this direction, there are different environmental conditions on the northern façade and under these harsh conditions, different material deteriorations are observed on the north façade compared to the south façade. The emergence of different material deteriorations between the facades is similar to the findings of Rishbeth [17].

In addition, it has been determined that the color change problem in the building is mostly on the south façade. This finding obtained in our study supports the study results of Paradise [20] which correlates with the higher incidence of color change problems on the south façade in stone material due to higher sun exposure on south-facing façades.

6. Conclusion

In this study, the deteriorations in the historical structure of Izzetpasa Old Prison in the central district of Mardin province were examined. When the structure was examined, it was observed that deterioration caused by physical, chemical and human effects was common. As physical deterioration in the structure: loss of surface, wear and joint discharge; as chemical degradation: surface pollution, color change examples are seen. In addition, there are deteriorations caused by human effects such as faulty repair and lack of maintenance.

In our study; It is thought that the detection and expression of material and material deterioration analysis in a geographical context will contribute to the literature in defining and diagnosing material problems in this geographical context. More specifically, degradation patterns can be identified, assisted by visual inspection, and mapped at different scales in a computer-aided design (CAD) or geographic information systems (GIS)

environment. Combining the above-mentioned data with a GIS system in future studies may help to monitor the life cycle of the structure under consideration in terms of sustainability. Mapping is a relatively cost-effective technique and, when combined with other onsite investigations, can help plan sampling and laboratory tests, reducing the cost of diagnostic and containment procedures.

In addition, in future studies, it will be possible to define the deterioration types of local limestone specific to Mardin more comprehensively; It is recommended to conduct studies using different integrated methodologies to be created by combining laser scanning and experimental analysis.

Funding

This research received no external funding.

Author contributions

Lale Karataş: Conceptualization, Methodology, Writing the manuscript **Tahir Ateş:** Data curation, Writing-Original draft preparation, **Aydın Alptekin:** Visualization, Investigation, Writing-Reviewing and Editing. **Murat Yakar:** Writing-Reviewing and Editing

Conflicts of interest

The authors declare no conflicts of interest.

References

1. Karataş, L., Alptekin, A., Kanun, E., & Yakar, M. (2022). Tarihi kârgir yapılarda taş malzeme bozulmalarının İHA fotogrametrisi kullanarak tespiti ve belgelenmesi: Mersin Kanlıdivane ören yeri vaka çalışması. *İçel Dergisi*, *2*(2), 41-49.
2. Dal, M., & Tokmak, M. (2020). Durability properties of Silivri limestone and usability in stone building restorations. *International Journal of Pure and Applied Sciences*, *6*(1), 33-41.
3. Türkeri, İ., & Özgen, C. (2021). Investigation of the Ottoman Period Masjids in the Izmit City Site: Structural Spatial and Liturgic Item Analysis. *Online Journal of Art and Design*, *9*(2), 189-202
4. Dal, M. (2021). The Deterioration Problems Observed in the Natural Building Blocks of Saint George Church in Diyarbakır Province. *Online Journal of Art and Design*, *9*(1), 254-262.
5. Dal, M., & Artık, K. (2008). Geleneksel Mimaride Taş Alterasyonu, MERSEM 2008 Türkiye VI. *Mermer ve Doğaltaş Sempozyumu*, 26-27.
6. Karataş, L., Alptekin, A., & Yakar, M. (2022). Determination of Stone Material Deteriorations on the Facades with the Combination of Terrestrial Laser Scanning and Photogrammetric Methods: Case Study of Historical Burdur Station Premises. *Advanced Geomatics*, *2*(2), 65-72.
7. Karataş, L., Alptekin, A., & Yakar, M. (2022). Detection and documentation of stone material deterioration in historical masonry structures using UAV photogrammetry: A case study of Mersin Aba Mausoleum. *Advanced UAV*, *2*(2), 51-64.
8. Karataş, L. (2022). Integration of 2D mapping, photogrammetry and virtual reality in documentation of material deterioration of stone buildings: Case of Mardin Şeyh Çabuk Mosque. *Advanced Engineering Science*, *2*, 135-146.
9. Karataş, L., & Menteşe, D. H. (2022). Dara Antik Kenti (Anastasiopolis) Nekropol Alanının Malzeme Sorunlarının Yersel Lazer Tarama Yönteminden Elde Edilen Ortofotolar Yardımıyla Belgelenmesi. *Türkiye Fotogrametri Dergisi*, *4*(2), 41-50.
10. Karataş, L., & Alptekin, A. (2022). Kagir Yapılardaki Taş Malzeme Bozulmalarının Lidar Tarama Yöntemi ile Belgelenmesi: Geleneksel Silvan Konağı Vaka Çalışması. *Türkiye Lidar Dergisi*, *4*(2), 71-84.
11. Karataş, L., Alptekin, A., & Yakar, M. (2022). Investigation of Molla Hari (Halil) Süleyman Paşa Mosque's material deteriorations. *Advanced Engineering Days (AED)*, *4*, 55-57.
12. Karataş, L., Alptekin, A., & Yakar, M. (2022). Material deteriorations occurring on the facades of the Mor Sergios Bakhos Church. *Advanced Engineering Days (AED)*, *4*, 48-51.
13. Dal, M., & Umaroğulları, G. (2014). A petrografic and chemical analysis of the degree of deformation in historical building stones in Edirne. *International Journal of Scientific Research*, *3*(3), 392-395.
14. Karataş, L. (2023). Investigating the historical building materials with spectroscopic and geophysical methods: A case study of Mardin Castle. *Turkish Journal of Engineering*, *7*(3), 266-278.

15. Karataş, L., Alptekin, A., & Yakar, M. (2022). Detection of materials and material deterioration in historical buildings by spectroscopic and petrographic methods: The example of Mardin Tamir Evi. *Engineering Applications*, *1*(2), 170-187.
16. Stefani, C., Brunetaud, X., Janvier-Badosa, S., Beck, K., De Luca, L., & Al-Mukhtar, M. (2014). Developing a toolkit for mapping and displaying stone alteration on a web-based documentation platform. *Journal of Cultural Heritage*, *15*(1), 1-9.
17. Rishbeth, J. (1948). The flora of Cambridge walls. *The Journal of Ecology*, 136-148.
18. Robinson, D. A., & Williams, R. B. G. (1996). An analysis of the weathering of Wealden sandstone churches. *Processes of urban stone decay*, 133-149.
19. Martinho, E., Dionísio, A., Almeida, F., Mendes, M., & Grangeia, C. (2014). Integrated geophysical approach for stone decay diagnosis in cultural heritage. *Construction and Building Materials*, *52*, 345-352.
20. Paradise, T. R., & Zayadine, F. (1999). Analysis of sandstone weathering of Roman theater in Petra, Jordan. *Annual of the Department of Antiquities of Jordan*, *43*, 353-368.
21. Price, C. A., & Doehne, E. (2011). Stone conservation: an overview of current research.
22. Siegesmund, S., Wiese, F., Klein, C., Huster, U., & Pötzl, C. (2022). Weathering phenomena, rock physical properties and long-term restoration intervention: a case study from the St. Johannis Chapel of Lütgenrode (Lower Saxony, Germany). *Environmental Earth Sciences*, *81*(15), 1-36.
23. Torney, C., Forster, A. M., & Szadurski, E. M. (2014). Specialist 'restoration mortars' for stone elements: a comparison of the physical properties of two stone repair materials. *Heritage Science*, *2*(1), 1-12.
24. Charola, A. E., & Ware, R. (2002). Acid deposition and the deterioration of stone: a brief review of a broad topic. *Geological society, London, special publications*, *205*(1), 393-406.
25. Searle, D. E., & Mitchell, D. J. (2004). Stone Weathering and Urban Particulate Pollution in the UK. *Stone Deterioration in Polluted Urban Environments*, 17-38.
26. Brimblecombe, P., & Grossi, C. M. (2007). Damage to buildings from future climate and pollution. *APT Bulletin: The Journal of Preservation Technology*, *38*(2/3), 13-18.
27. Siegesmund, S., Ruedrich, J., & Koch, A. (2008). Marble bowing: comparative studies of three different public building facades. *Environmental Geology*, *56*(3), 473-494.
28. Snethlage, R., & Sterflinger, K. (2011). Stone conservation. In *Stone in architecture* (pp. 411-544). Springer, Berlin, Heidelberg.
29. Popovics, J. S. (2003). NDE techniques for concrete and masonry structures. *Progress in Structural Engineering and Materials*, *5*(2), 49-59.
30. Chastre, C., & Ludovico-Marques, M. (2018). Nondestructive testing methodology to assess the conservation of historic stone buildings and monuments. In *Handbook of Materials Failure Analysis* (pp. 255-294). Butterworth-Heinemann.
31. Vergès-Belmin, V., Heritage, A., & Bourgès, A. (2011). Powdered cellulose poultices in stone and wall painting conservation-myths and realities. *Studies in conservation*, *56*(4), 281-297.
32. Fitzner, B., Heinrichs, K., & Kownatzki, R. (1995). *Weathering Forms, Classification and Mapping: Verwitterungsformen-Klassifizierung und Kartierung*. Ernst and Sohn.
33. Mardin Müzesi Restorasyon-Konservasyon Analiz Laboratuvarı (2012). Mardin'de tarihi yapılarda kullanılan taşların analizi sayılı teknik raporu, 2012/34.
34. Karataş, L. (2016). *Mardin Kentsel Sit Alanındaki İbadet Yapılarında Malzeme Kullanımı ve Sorunları Üzerine Bir Araştırma* (Master's Thesis, Uludağ University, Fen Bilimleri Enstitüsü, Bursa, 340p).