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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

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ABSTRACT

Mapping the surface patterns of the stone is a non-destructive procedure, which has a critical importance for the qualitative and quantitative assessment of conservation status. Besides, the mapping technique, which is used to explain the segregation categories and to calculate the damage indexes, is a time-consuming task that is generally performed manually. Therefore, practical methods must be developed for the conservation specialists to automatize deterioration mapping without increasing the cost of diagnosis process significantly. Within this context, the aim of the study is to present a methodology, which combines the terrestrial laser scanner technology with the photogrammetric techniques, to investigate the damages on the stone materials that form the historical buildings. Methods of literature review, observational determination, terrestrial laser scanning, and photogrammetry were used in the study, in order to create the material deterioration analytic relievos of the facades of the specified building. The findings were assessed with the descriptive and systematic analysis methods. It is seen that the data required to assess the conservational status of the materials in the historical buildings can be obtained through obtaining a thematic map of the damages that affect the stone construction materials within the scope of the study. According to the findings, it is found that one of the main problems regarding this monument is the formation of plants.

1. INTRODUCTION

In recent years, an increase is seen in the material deteriorations of cultural heritage structures, which have been built from stone materials, in the world (Bal'awi et al., 2012; Price, 1996). When the studies, which address the material deteriorations of stone monumental structures in the world, are reviewed, it is observed that the sources causing an increase in the deteriorations are the factors such as the saline effect, increase of air pollution, and humidity that increases due to climate change (Corvo et al., 2010; Fort et al., 2004; Moroni et al., 2004; Spezzano, 2021; Webb et al., 1992). With the increase of material deteriorations, the need to determine the material deteriorations of the stone structures accurately and document them immediately has been increased (Alptekin et al., 2019a; Yakar & Alptekin, 2021; Kanun et al., 2022). Mapping the surface patterns of the stone is a non-destructive procedure, which has a critical importance for the qualitative and quantitative assessment of conservation status (Yılmaz & Yakar 2006; Yakar et al. 2014). Besides, the mapping technique, which is used to explain the segregation categories and to calculate the damage indexes, is a time-consuming task that is generally performed manually. Therefore, practical methods must be developed for the conservation specialists to automatize deterioration

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mapping without increasing the cost of diagnosis process significantly (Adamopoulos & Rinaudo, 2021).

Today, the use of various techniques in documentation has become necessary, because the manual documentation is insufficient and causes loss of time. Therefore, today it has become common to document the structures via various techniques such as photogrammetric and laser scanning methods in order to investigate and diagnose the damages on the materials forming the monuments, and to improve the production process of the thematic maps (Yakar 2010 et al. 2010; Lerma & Herráez, 1999). The non-destructive techniques are the subjects that many conservation and restoration specialists focus on importantly in the documentation of material deteriorations of historical structures (Genovese, 2005; Alptekin et al 2019b). Terrestrial laser scanning is a non-destructive technique, and today terrestrial laser scanning has made great advances in the field of documenting the architectural characteristics and material deteriorations of the structures, in which the direct contact is not involved (Alptekin et al. 2019c; Ulvi & Yakar 2014; Ulvi et al. 2014; Kanun et al.2021; Korumaz et al. 2010). Various studies in the literature verify that the technologies such as photogrammetric and laser scanning methods create great convenience and saving of time in the documentation of architectural and material problems (Alptekin & Yakar 2020a; Alptekin & Yakar 2020b). In the study conducted by Ercoli et al., (2012), which is a significant example, it was verified that terrestrial laser scanning may be an important alternative to the technique of determination on-site in the determination of material deteriorations for the monumental structures. As a result of the study, it was found that the information obtained via terrestrial laser scanning made the understanding of the textural features and experimental results easier and provided sufficient information to determine the material problems. Furthermore, it was proven that the terrestrial laser scanning was able to determine the segregation degree of the stone material in detail and it was more effective and cheaper than the direct measurements, which are potentially harmful for the worn surfaces. In another example, Armesto-González et al., (2010) have combined the terrestrial laser scanning technology with the digital image processing techniques in order to investigate the damages on the stone materials forming the historical buildings, and explained that the intensity data received from the terrestrial laser scanner is sufficient for the recognition and characterization of certain pathologies on the stone construction materials forming the historical buildings. In another example, Lanaro et al., (1998) have verified that important information may be obtained about the textural features (for example; micro fractures, micro roughness, rock porosity) on the material by using terrestrial laser scanner. Randazzo et al., (2020) have classified the types of stone material deterioration using photogrammetric methods in the determination of stone material deteriorations on the structure, and found that using the photogrammetric examination provides a higher resolution image collection for more advanced quantitative analysis and the relevant deterioration assessment of stone material deteriorations. Adamopoulos & Rinaudo, (2021) found in their study that applying the photogrammetric techniques to document the stone material deteriorations facilitates obtaining data, which simplify the extraction of thematic information and the development of deterioration maps. Bal'awi et al., (2012) have combined laser scanning and photogrammetry and a comprehensive approach that utilizes 2D-3D documentation of the structure with the results of laboratory analysis, and reached to a conclusion that data and digital images received from the laser scanner provide sufficient data to increase the visual quality of 3D surface details and cracks.

As explained also in the literature, terrestrial laser scanning and photogrammetry techniques provide great benefits in the diagnosis of material problems. Within this context, the aim of the study is to present a methodology, which combines the terrestrial laser scanner technology with the photogrammetric techniques, to investigate the damages on the stone materials that form the historical buildings. The data required to assess the conservation status of the materials in the historical buildings were obtained through obtaining a thematic map of the damages that affect the stone construction materials within the scope of the study. Thus, it was possible to suggest the acts appropriate for the restoration and conservation of the building. According to the findings, it is seen that one of the main problems regarding this monument is the damage of saline.

1.1. Location, History and Architectural Analysis of the Building

The building is located in central Burdur, Bağlar Neighbourhood, on Ofis Avenue. According to the land registration records it is located on Block 46, Plot Nr. 1.

Isparta – Burdur stations and their auxiliary structures have been built in 1936, within the period called early republic period, and are modern buildings, which have been built in the second national architectural character by using the modern construction materials of the period. The station buildings and their auxiliary structures are masonry constructions with reinforced girders in general, in which cut stones have been used on the main outer walls, turning to reinforced concrete carcass in some parts. In addition, local köfke stone (pumice stone), which is relatively processed easily, has been used on the exterior walls. Mosaic has been poured on all interior floors of the station building and its auxiliary structures, the interior walls and the ceilings have been whitewashed after plastering with a plaster containing cement and lime mortar. Marseilles tile has been selected as the roof covering material.

The station premises, which has been built with cut stone, is a complex building. The main station premises are consisted of a basement and ground floor. Two lodgings are located on the +3.28 elevation. On this floor, the lodgings have been separated by naming them as east and west. Finally, the single-storey hangar building, which is covered with hipped roof, is located on the east part adjacent to the station premises.

1.2. Facade Characteristics

The north facade of the station premises has been built by cut stones and the door and window apertures have been placed in line with certain symmetry on the facade. A decorative side-coating has been made in the height of three lines of cut stones from the ground elevation of the facade. The ground and first floors are seen on the facade and the floors have been separated via cut stone moulding. A wooden separator has been placed on the middle point of the facade on ground floor, and thus entrance to the station premises has been provided. The wooden separator has been covered with concrete soffit, and the metal signboard of Turkish State Railways (TCDD) is seen of the front face of the soffit. Two wooden door and one wooden window apertures have been placed on the west of the wooden separator. The door and window apertures having the same features and form have been placed also on the east of it. The door apertures are in rectangular form having cut stone jambs. On the upper floor, eight window apertures, in the same type, have been placed. Apertures have cut stone sills and cut stone jambs. Concrete soffit in a depth of 1.30 meters, metal rain gutter, Marseilles tile roof covering constitutes the upper elevation of the facade. In addition, plastered chimneys of the buildings are seen and the upper elevation of the building mass, which has been built adjacent to the main building on the west of the structure, ends with the cut stone wall coping.

The South facade of the station premises has almost the same characteristics with the north facade. The only difference from the north facade is the change on the door and window apertures opened. The ground floor is consisted of a wooden separator on the middle point, as on the north facade, and the door and window apertures placed on the east and west of the separator. There are rectangular-formed windows having iron railings, cut stone sills and lintels, and doors having cut stone jambs on both sides of the separator. There are nine windows on the first floor, which has been separated via cut stone moulding. Window forms and styles differentiate. The large rectangular window aperture, which is placed on the west of the facade, does not reflect the characteristic of the period. Two window apertures opened on the facade are seen on the building mass, which has been built adjacent to the main building on the west of the facade. The upper elevation of this building mass ends with cut stone wall coping. Concrete soffit in a depth of 1.30 meters, metal rain gutter, Marseilles tile roof covering constitutes the upper elevation of the facade, and in addition, plastered chimneys of the buildings are seen.

The east facade, which constitutes the rear facade of the hangar building, is built from cut stones, as on the other facades. There is one wooden window on the facade. Both sides of this unoriginal window aperture are closed with jerry-built wall. It is seen that this area had a rectangular-formed, almost square, window aperture originally. Wooden eaves plate, Marseilles tile and plastered chimney constitute the upper elevation of the facade.

The facade, which constitutes the west of the station premises, is made of cut stone. It is seen that upper elevation difference between the station premises and this building mass has been utilised as a terrace opening to the west of the main building. A decorative side-coating has been made in the height of two lines of cut stones from the ground elevation of the facade. Wooden window having cut stone lintel and cut stone sill and one wooden door aperture having cut stone lintel have been placed on the facade. The cut stone moulding, which we see on the north and south facades, has been continued also on this facade without interruption. Cut stone wall coping constitutes the upper elevation of the facade. In addition, two wooden window apertures of the first floor of station premises, which continues on the rear side of the facade, are also seen. Window apertures are original. Concrete soffit, metal rain gutter, Marseilles tile roof covering constitutes the upper elevation of the station premises.

2. METHOD

Methods of literature review, observational determination, terrestrial laser scanning and photogrammetry were used in the study, in order to create the material deterioration analytic relievos of the facades of the specified building. The findings were assessed with the descriptive and systematic analysis methods. In the first stage of the study, a situation analysis was conducted about the historical building, on which the case study shall be carried out, and the general information of the building was presented under an archive review. Besides, an observational analysis was carried out on the building in order to document the material deteriorations of the building, and the deteriorations determined on the materials were presented in Part 2.1 as a chart. The chart prepared under the study is chart regarding the determination and documentation of the stone material deteriorations on the facades (Chart 1). In the second stage of the study, the stages followed to prepare the facade drawings of the building and the analytic relievos regarding the material deteriorations occurred on the facades using the terrestrial laser scanning and photogrammetric methods were explained systematically in Part 2.2. and 2.3.

2.1. Determination of the Material Problems

In this stage, within the first step of evaluating the conservation status of the building, an observational investigation, which is consisted of damage mapping, was carried out. Stone material deteriorations occurred on the facades of the building were marked in ''Table 1.''.

Table 1. Stone material deteriorations on the facades of Burdur Station Premises

NATURAL STONE CONSTRUCTION ELEMENTS				PROBLEMS ENCOUNTERED ON CONSTRUCTION ELEMENTS MADE OF MASONRY MATERIAL IN BURDUR STATION PREMISES																				
																						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 BEARINGS	Leg		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Column		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	CONTINUOUS BEARINGS	Wall		X	-	-	-	-	-	-	-	X	-	-	-	X	-	-	-	-	-	X	X	X
HORIZONTAL BEARINGS	FLOORINGS	Flat		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Curvilinear -		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WALL OPENINGS		Window	Lintel/jamb	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Sill	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Door	Lintel/jamb	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Sill	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-
		Arch		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AUXILIARY ELEMENTS		Network																						
		Moulding																						
		Gargoyle																						
		Chimney																						
		Element for passage to the cover																						

2.2. Scanning Procedure and Data Processing

Terrestrial laser scanning method was used in scanning procedure in this stage, in order to document the building as 3-dimensional. Exterior facade scanning was carried out by using laser scanning device (Faro Focus Laser Scanner), and point cloud of the building was obtained in the scanning procedure (''Fig. 1'').

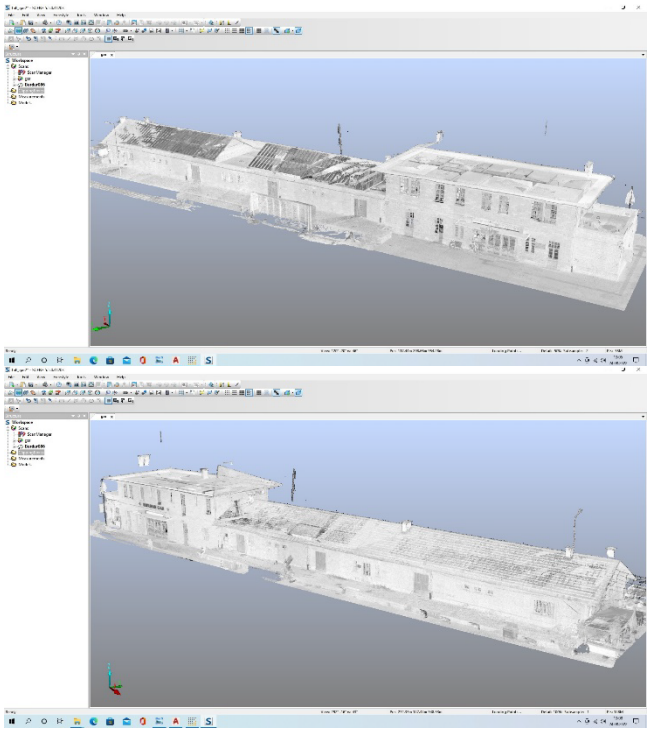

Figure 1. Point cloud obtained regarding the building

2.3. Obtaining the Orthophotograph Images

In this stage, orthophotograph images of the building were acquired from the point clouds obtained in the laser scanning procedure in the software named PointCab Origins 3.9 (''Fig. 2-7'').

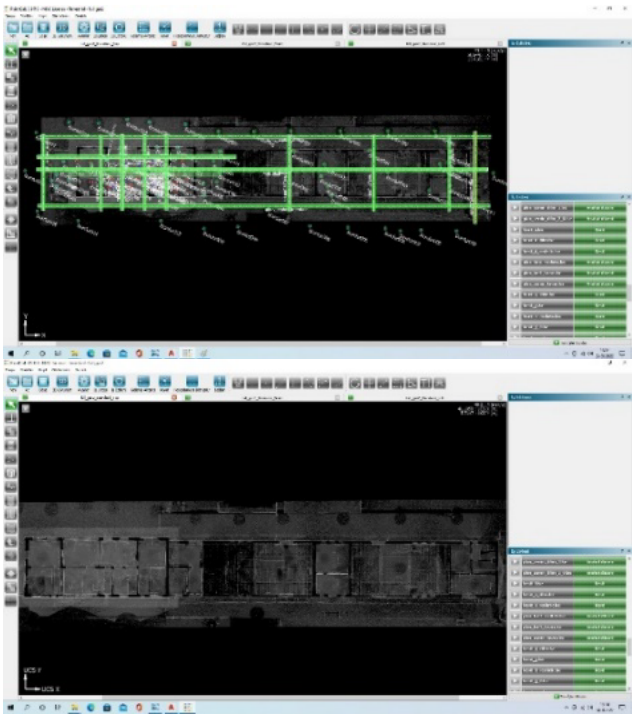

Figure 2. Scene of creating orthophotographs from the point cloud obtained from Terrestrial Laser Scanning, using the programme named PointCab Origins 3.9

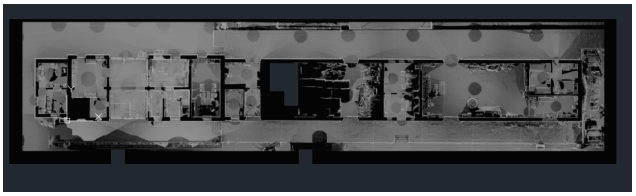

Figure 3. Orthophoto of ground floor plan

Figure 4. Orthophoto of west frontage

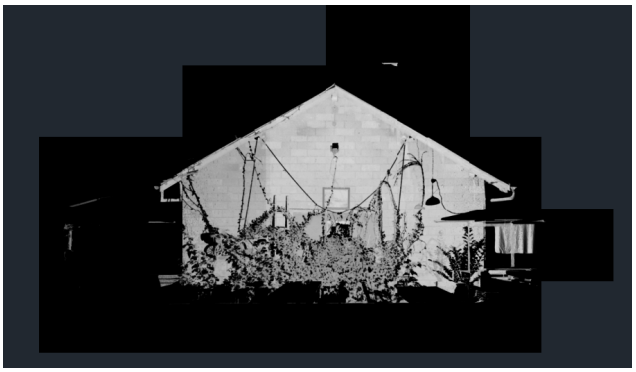

Figure 5. Orthophoto of east frontage

Figure 6. Orthophoto of south frontage

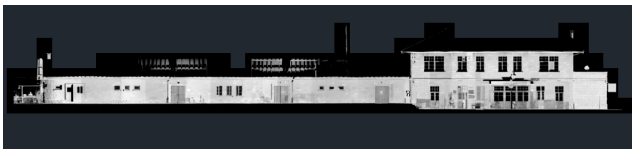

Figure 7. Orthophoto of north frontage

AutoCAD programme was used in the procedure of creating the drawings of the facades. Before commencing the drawing procedure, the orthophotograph images produced in the software named PointCab Origins 4.0 were transferred to AutoCAD environment. They can be transferred into AutoCAD media in the format of TİF file with tif. or .tiff extension, which is the common data format of AutoCAD software. Facade drawings of the building were obtained through AutoCAD programme, using the scaled orthophoto images obtained.

3. RESULTS

The material deteriorations, which were determined in Part 2.1. in "Table 1.", were processed on the drawings analytically. In this section, analytic relievo layouts, which were obtained regarding the material damages, are presented. The damage determination layouts prepared are mapped according to the colours specified in "Fig. 8".

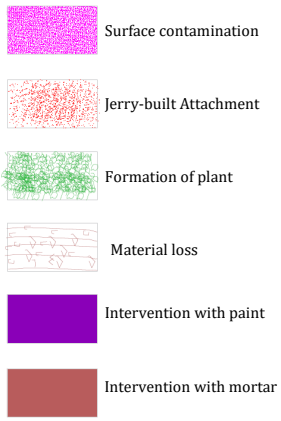

Figure 8. Legend regarding the material damage layouts

3.1. Analytic Relievos Regarding the Stone Material Deteriorations

Deteriorations and deformations such as intervention with reinforced concrete plaster, surface contamination, and material losses were observed on the cut stone surfaces, on the north frontage. Besides, jerry-built attachments such as the electric cables, speakers, and signboard are also present on the facade ("Fig. 9").

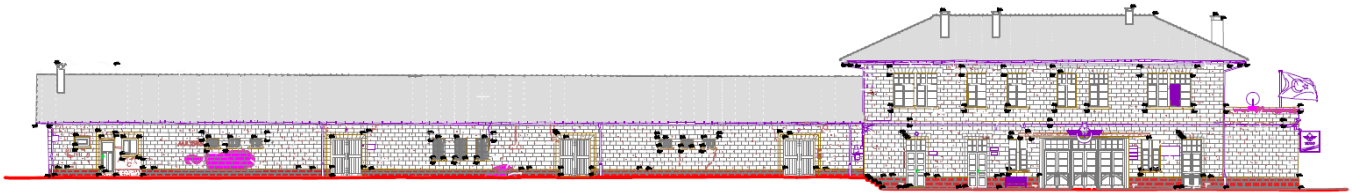

Figure 9. The north frontage

Deteriorations such as formation of plants, surface contamination, material losses on the window sills are seen on cut stone surfaces constituting the south frontage. Besides, there are numerous jerry-built attachments are present on the facade ("Fig. 10").

Figure 10. The south frontage

Majority of the east frontage is covered with ivy plant, and it is seen that the front of the facade is utilized as a cafe. Jerry-built attachments and deteriorations such as the surface contamination were observed (''Fig. 11'').

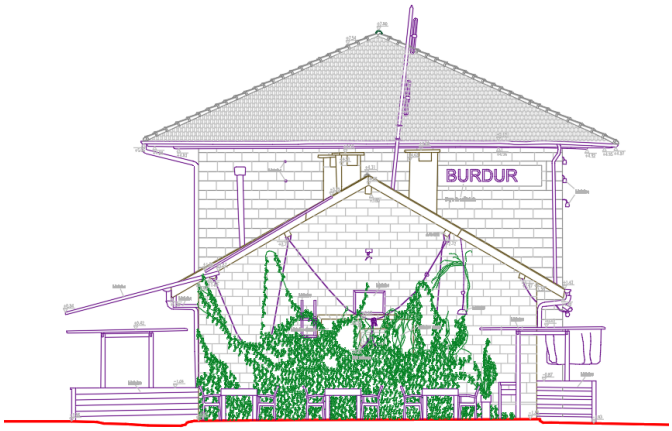

Figure 11. The east frontage

It is seen that intervention has been made on the sign plate within the rectangular frame created by cut stones with paint on the west frontage. Deformation and surface contamination, and various jerry-built attachments such as cables and antenna are seen on the surface of the cut stone facade (''Fig. 12'').

Figure 12. The west frontage

4. DISCUSSION

The aim of the study is to suggest a methodology that combines the terrestrial laser scanning with photogrammetric methods in order to investigate the damages on the stone materials, which constitute the historical buildings. The data required to assess the conservation status of the materials in the historical buildings were obtained through obtaining a thematic map of the damages that affect the stone construction materials within the scope of the study. Thus, it is possible to suggest the acts appropriate for the restoration and conservation of the building. According to the findings, it is seen that one of the main problems regarding this monument is the plant formation. It was seen that the water leaking from the surrounding resources have risen via capillarity, and caused formation of plants on the facades of the building. Another significant deterioration type is the surface contamination. It was determined that the factor causing surface contamination is the waters flowing from the roof of the building to the facade and causing contaminations on the surface. Within this scope, it is concluded that the greatest factor causing stone material deteriorations is water-originated, which affects the building reflexively.

In the study, it was enabled to document the architectural drawings and material deteriorations of the building through the method used by combining the laser scanning and photogrammetric techniques. This finding supports the studies, which emphasize that laser scanning and photogrammetric techniques provide sufficient data to document the architectural drawings and material deteriorations of the building. (Armesto-González et al., 2010; Bal'awi et al., 2012; Ercoli et al., 2012; Lanaro et al., 1998; Randazzo et al., 2020),

Furthermore, as a result of the study, it was found that determination and documentation of the material deteriorations can be carried out within a short period and obtaining data, which simplifies the development of deterioration maps, is facilitated. This finding supports the study results of Adamopoulos & Rinaudo (2021), which have determined that applying the photogrammetric techniques to document the stone material deteriorations facilitates obtaining data, which simplify the extraction of thematic information and the development of deterioration maps.

5. CONCLUSION

The data required to assess the conservational status of the materials in the historical buildings were obtained through obtaining a thematic map of the damages that affect the stone construction materials within the scope of the study. According to the findings, it is found that one of the main problems regarding this monument is the formation of plants and surface contamination. It is concluded that both stone deterioration types are water-originated, which affects the building reflexively. Within this scope, the most important point is that the excessive water, which affects the building, must be removed. The approaches intended only to repair the stone material, without eliminating this main problem, shall only save the moment, and cause greater problems for the building and greater damages on the stone materials due to not eliminating the

problem completely. Within this context, in the study it is suggested that the water affecting the building must be removed. In the following stage, the problems of formation of plant and surface contamination must be cleaned mechanically and surface protective materials must be applied on the stone materials in accordance with the opinions of the specialists.

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Author contributions

Lale Karataş; Methodology, data collection, writing, control. Aydın Alptekin; Control. Murat Yakar: Edit the paper

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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