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Analytical Documentation of Stone Material Deteriorations on Facades with Terrestrial Laser Scanning and Photogrammetric Methods: Case Study of Şanlıurfa Kışla Mosque

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Terrestrial Laser Scanning,
Orthophoto,
Material Deterioration,
Stone Material.

ABSTRACT

Şanlıurfa Kışla Mosque, in its geographical context, is of great importance with its historical importance and architectural features as it reflects the tangible and intangible cultural heritage. However, it is seen that the structure is worn out due to various factors and is exposed to various material problems. In terms of the continuity of the cultural heritage, it is necessary to determine the material problems before the destruction of the building, to document it and to take precautions for protection. The aim of the study in this context is to detect and analytically document the material deterioration on the facades of Şanlıurfa Kışla Mosque. As a method in the study; observational detection and terrestrial laser scanning technique were used. The results of the study support the fact that the method used provides great savings in terms of time and effort in the production of architectural drawings and damage maps, which is the result obtained in many studies in the literature. In addition, as a result of the study, it was determined that the most common type of material deterioration in the building was surface pollution. In the geographical context determined by the study, it is expected to detect the dangers related to stone structures and to take measures to prevent the hazards related to the structures.

1. INTRODUCTION

Stone structures form a large part of the cultural heritage in the world. Many historical structures such as the ancient city walls in China and the monumental structures in Europe are made of stone materials. However, stone materials expose to deteriorations today due to various factors and the structures encounter the risk of extinction (Alptekin et al., 2019; Karataş,2016; 2022; Karataş et al., 2022; Kanun et al.,2022; Shen et al., 2019; Yakar & Alptekin, 2021). When the studies, which investigate the causes of deteriorations of the stone structures in the world, are reviewed in the literature, it is emphasized that recently the factors arising from the air pollution mostly cause stone material deterioration (Ambrosini et al., 2019; Corvo et al., 2010; Comite et al., 2017; Comite et al., 2020; Falchi et al., 2019; Gibeaux et al., 2018; Graue et al., 2013; Ivaskova et al., 2015; Rovella et al., 2020; Vidorni et al., 2019; Vidal et al., 2018; Webb et al.,1992). The common point of these studies is the highlighting on the requirement of conducting studies to identify the deterioration factors, to which the stone structures expose mostly within the geographic context in different countries, and thus to determine the factors, of which the cultural heritage of the world is under the threat. Based on these requirements emphasized in the literature, investigations have been carried out on stone structures in different countries. In the studies conducted in Havana, Cuba and San Francisco, Mexico cities, it was concluded that atmospheric deterioration of the stone was intensified with the impacts on the appearance and integrity of valuable historic buildings,

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which have been built by using limestone, due to air pollution and humidity (Corvo et al., 2010). Another example conducted by Ivaskova et al. (2015) documented that the factors such as the climate parameters and atmospheric pollution became a serious problem increasingly not only in Slovakia, but also in the whole world, and the air pollution causes a great deterioration effect on the stone materials in the Republic of Slovakia. Rovella et al. (2020) determined that the vehicle traffic and the industrial activities, which are the main contaminant resources in Cairo, are the greatest deterioration causes on the stone structures. In the study conducted by Arroyo et al. (2013) on the stone structures in Naples city, it was suggested that the compound of materials and mortars used in the restorations carried out on these structures previously are sulphate-rich, and the use of this faulty material is the greatest cause of deterioration on the stone structures in Naples city. Comite et al. (2020) emphasize the importance of the impact of local sources of pollution on the cultural heritage in Italian and European cities. Another deterioration cause that is emphasized is the fact that the rate of stone deterioration related with the “memory effect of construction stones” also depends on the environmental conditions, to which the stone exposed in the past (Vleugels et al., 1993).

As emphasized also in the studies explained above, it is important to reveal and document the stone material problems and causes of deterioration, within the context of identifying the deterioration factors, to which the stone structures expose mostly within the geographic context in different countries, and thus determining the factors, of which the cultural heritage, which constitutes the stone structures in the world, is under the threat. Documentation is a valuable tool to preserve the heritage resources. However, manual methods are time-consuming and troublesome in the procedure of documenting the material problems.

Today, there have been many innovations in the documentation of the cultural heritage with the developing technology, modern documentation techniques have advanced rapidly, and the data obtained from the methods such as terrestrial laser scanning and photogrammetry started to be used as base in the documentation of the material deteriorations. Traditional methods used in the documentation of material deterioration in historical buildings are inadequate in terms of time and effort today (Barber et al.,2006). In studies in the literature; It is emphasized that the use of terrestrial laser scanning methods, instead of traditional methods that require long and laborious measurements, brings great convenience, especially in the documentation and evaluation of stone surfaces. When the studies are examined, it is seen that the analytical drawings required to document material deteriorations can be obtained easily and in a very short time frame by using the terrestrial laser scanning method (Alptekin et al.,2019; Alyilmaz,2010; Burgerb et al.,2007; Casula et al.,2009; Curso et al. .,2017; Darap et al.,2007; Ercoli et al.,2013; Fais et al.,2017; González et al., 2010; Karataş et al.,2022; Kottke et al.,2011; Korumaza et al.,2010; Yakar et al.,2015; Meroño et al.,2015; Pozo et al.,2016; Willis & Sui,2010; Pesci et al., 2011; Ulvi et al.,2016; Tutzauer & Haala (2015); Şasi. & Yakar, 2017; Ulvi & Yakar,2010; Yakar et al.,2009; Yakar et al.,2015; Yakar & Mirdan, 2017; Yakar & Dogan, 2019; Yakar & Omar ,2016; Yakar, 2015; Yılmaz, & Yakar, 2006; Schnabel et al., 2010 ; Quagliarini et al.,2017). An important example is the study of Corso et al. (2017); which combined the image layers obtained from terrestrial laser technology with the data obtained from on-site examination in order to diagnose the material deteriorations of stone facades. As a result of the study, it is verified that the degradation patterns such as surface roughness, stone relief, stone erosion or change, color change on the stone can be easily detected with the method used.

Another technique that is widely used in the literature for the documentation of material deterioration of stone structures; These are the studies that obtain the data that will be the basis for creating orthophotos by transferring the data obtained from terrestrial laser scanning to various software and defining the types of material deterioration over them. Orthophoto image; They are digital images in which errors caused by curvature, rotation and height difference are corrected and made into vertical projections.

Many studies in the literature confirm that orthophoto images, which can be created with various software, are very useful data for architectural documentation, thanks to point clouds obtained from laser scanning data. In these studies, it is confirmed that thematic maps can be obtained by utilizing orthophotos with a three-dimensional model obtained with terrestrial laser scanning data (Mol et al., 2020; Stober et al., 2018; Gabriele et al., 2010; Meroño et al., 2015; Comert et al., 2012; Yılmaz and Yakar 2006).

It is also suggested in various studies that the use of orthophotos obtained by photogrammetric methods is practicable in the documentation of material problems. In a significant example, in which the orthophotos are used to document Roman amphitheatre in the centre of Amman, its surrounding and its material problems, it was enabled to digitise all important spatial information for the site with the orthophotos (Rawashdeh, 2013). Another study conducted by Widartono & Fitri (2016) has mapped the areas of Ijo temple complex using orthophoto images and suggested that orthophoto image maps can be used as base in the documentation of material problems and building. Perfetti et al. (2019) revealed that to produce the architectural drawings (sections and plans) with the production of orthophotos obtained via the photogrammetric methods from the data in laser scanning is sufficient. Yilmaz et al. (2007) emphasize the superior aspects of photogrammetry in restoration projects, compared to the traditional methods, in their study. Furthermore, he suggests that the orthophoto images obtained from the digital and 3D data via photogrammetry provide the information required for documentation, and besides these methods are easier, more precise, and enables saving of time in scaled drawing projects and in the determination of material problems, when compared with the classic methods. In the study, the facade drawings and 3-dimensional model of the building could be completed using numeric short-distance photogrammetry, and it was determined that digital short-distance photogrammetry makes contribution to the scaled drawing, zoning and restoration projects.

In addition, in the literature the computerized methods and short-distance photogrammetry are recommended as a preventive method that enables us to determine, measure and monitor the time wise evolution of some structural problems (Arias et al., 2005)

As specified previously, in the literature it is emphasized that it is necessary to conduct studies to identify the deterioration factors, to which the stone structures expose mostly within the geographic context in different countries, and to determine the factors, of which the cultural heritage of the world is under the threat. Within this context, the aim of this study is to produce orthophotographs from the data obtained by terrestrial laser scanning with the photogrammetric methods, and to document the facade drawings and the material deteriorations occurring on the facades analytically with the method of using the produced orthophotographs as base. It is expected that measures shall increase in the future to prevent the danger regarding the structures, with the determination of the dangers regarding the stone structures within the geographic context, which were found with the study conducted.

1.1. Location of the Building

The building is located in the centre of Şanlıurfa Viranşehir County, Kışla Neighbourhood(Figure 1).

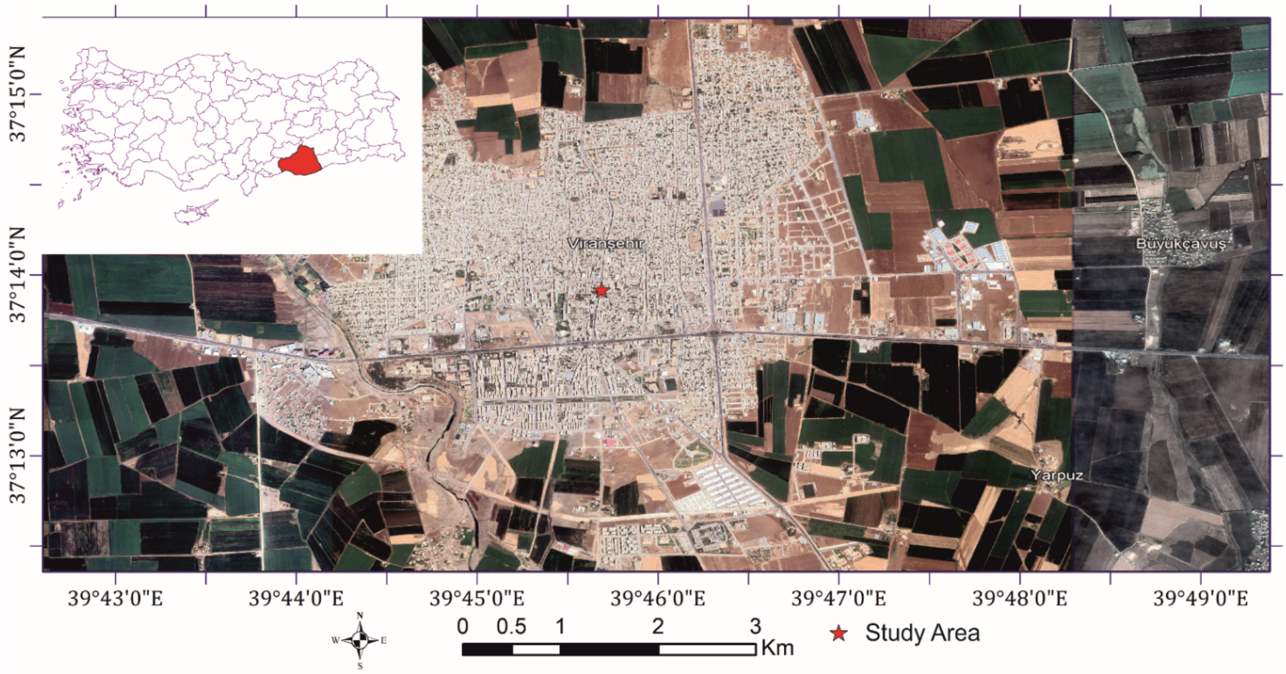

Figure 1. Location of Şanlıurfa Kışla Mosque

1.2. History and Architectural Analysis of the Building

The year of construction of the Mosque is not known. However, it is estimated that the building was built at the end of XIX. century. The epigraph dated H.1343\M.1923 located on the east frontage of the bedplate of the minaret is an epitaph. In addition to this, the epigraph placed within the mosque is undated, and related with the extension of the mosque.

The mosque was built from smooth cut stones and in rectangular plan with pole covers. Cover system was transformed into flat reinforced concrete roof in recent years. Recently, a narthex and women's gathering place were added to the front side of the mosque. The muezzin gathering place, which extends along the North wall, in the direction of entrance within the sanctuary, was made of wood and settles on two columns on the front side. The mihrab has round niche and made of cut stone, and its mimbar is made of wood. The minaret, which is located in northwest, was made of cut stone and has a minaret balcony with stalactite. The guardrail of the minaret balcony is iron.

Kışla Mosque is within the mosque group, which has single plate parallel to the mihrab and pole covers. The Mosque is consisted of the narthex placed on the North entrance section and of the upper gathering place and sanctuary placed above it. The minaret rises above the reinforced concrete flat roof on the northeast of the building. The mihrab is placed on the middle axe of mosque's South wall, and the mimbar is placed just on the west of it. The mihrab, which has a round niche and made of cut stone, and the wooden mimbar has been left as far as plain and without ornaments.

WC and lodging are located on the northwest; muezzin lodging, depot, building of Quran Course and the lodging on its first floor are located on the north of Kışla Mosques, which is shaped with the courtyard and its surrounding units. Shadirvan is located on the front side of mosque's east frontage. In addition, the section of burial area (reserved for special people) is located on the southwest of Kışla Mosque.

2. METHOD

The material deterioration of the facades of the building determined in the study was carried out with a literature search on the original state of the building in the first stage to create analytical surveys.

In the next stage, in order to understand the current situation of the building, the material deteriorations on the facades were determined by making observations. The determined material deteriorations were classified according to the structural elements of the stone structures and recorded in the table prepared in order to represent the material deteriorations in a systematic way. The prepared schedule is explained in section 2.2 (Table 1).

In the next stage of the study, a laser scanning device (Faro Focus Laser Scanner) was used in the part of the building's facades in order to obtain images of the facades of the building and point clouds were obtained during the scanning. Objects up to 330 meters away can be scanned with the device used (see Figure 2).

Figure 2. Laser Scanner (The Focus3D X 330)

The obtained data were processed in the PointCab Origins 3.9 program and scaled orthophotos (upright photo) of the building facades were obtained. Orthophoto image are the numerical images, which the errors arising due to the inclination, toe and height differences are rectified and transformed into vertical projections.

Orthophoto images, which may be formed through various software, thanks to the point clouds obtained from laser scanning data, are very useful products for architectural documentation. Since the orthophoto images obtained are scaled, identical images of the structures may be obtained. Therefore, ortophoto images can be used as base in architectural drawings. The orthophoto images obtained from the points clouds enable to make measurements on the plans and sections with millimetric precision in office environment (Comert et al., 2012; Ulvi and Yakar 2014; Alptekin and Yakar 2020).

Analytical survey drawings were obtained by using scaled orthophotos of the facades obtained. Section 2.2 on the analytical survey drawings obtained. The stone material deterioration types detected in the study were analyzed analytically. The figure below summarizes the situation regarding the workflow of the work done (Figure 3).

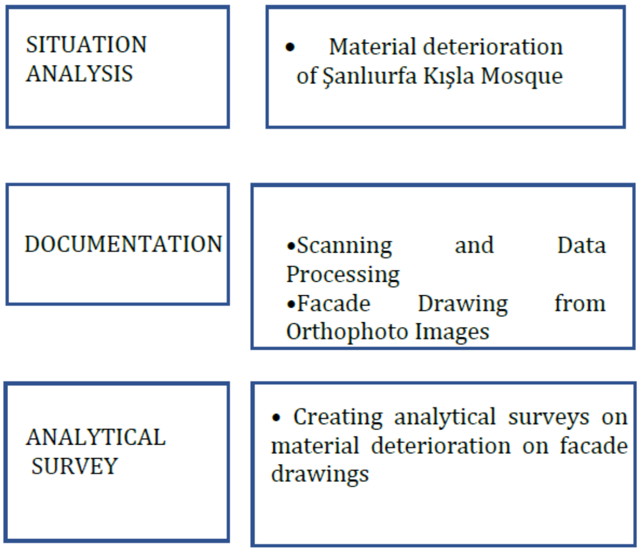

Figure 3. Workflow showing recommended process for orthophoto generation and integration from terrestrial laser scan data in documenting material deterioration

2.1. Situation Analysis

In order to understand the relationship of the building with its environment before making conservation proposals for the building, it is necessary to conduct research on the building in terms of its general structure, form, material and environment (Karkaş and Özgünler, 2021). All information about the historical documents about the building, its changes over time and material deterioration in the current situation were collected.

2.2. Determination of 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 Mosque were explained in ‘’Table 1.’’.

Table 1. Stone material deteriorations on the facades of Kışla Mosque

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																						

2.3. 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. 4”).

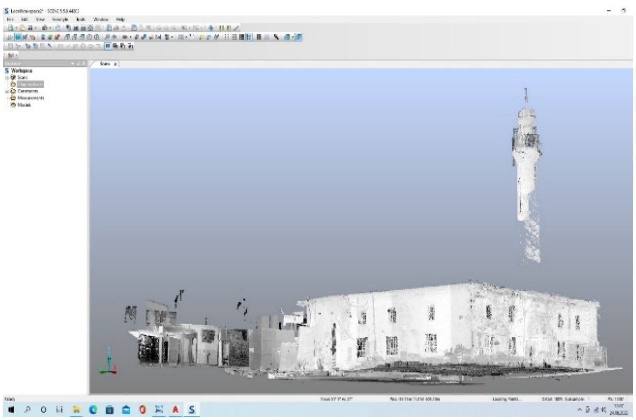

Figure 4. Point cloud obtained regarding the building

2.4. Obtaining the Orthophotograph Images

In this stage, orthophotograph images of the building were obtained from the point clouds obtained in the laser scanning procedure in the software named PointCab Origins 3.9 (“Fig. 5-11”).

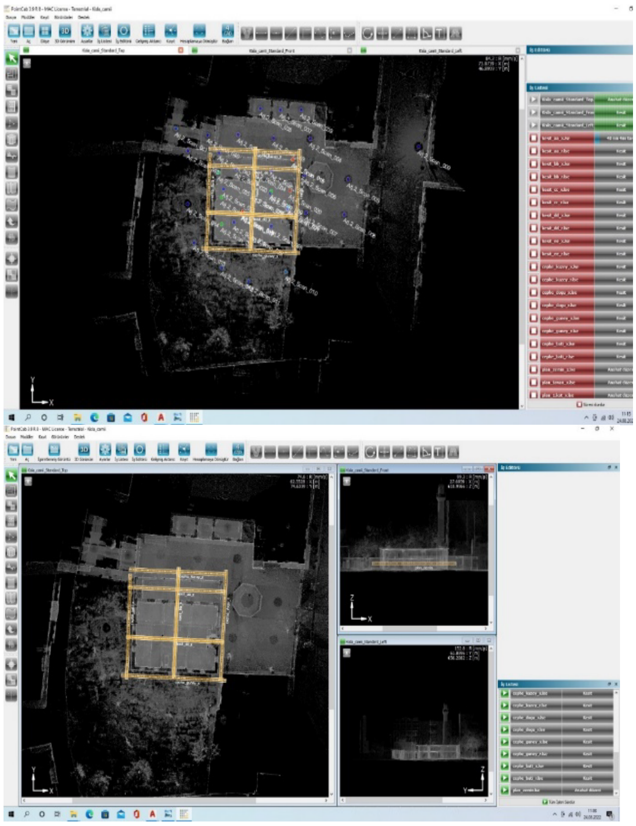

Figure 5. Scene of creating orthophotographs from the point cloud obtained from Terrestrial Laser Scanning, using the programme named PointCab Origins 3.9

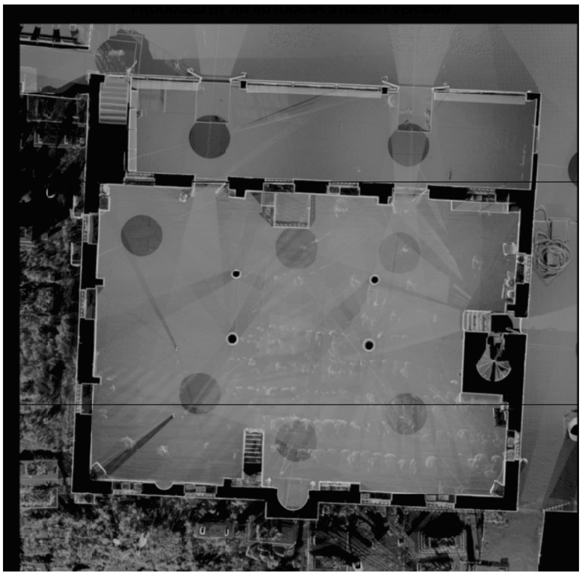

Figure 6. Orthophoto of layout plan

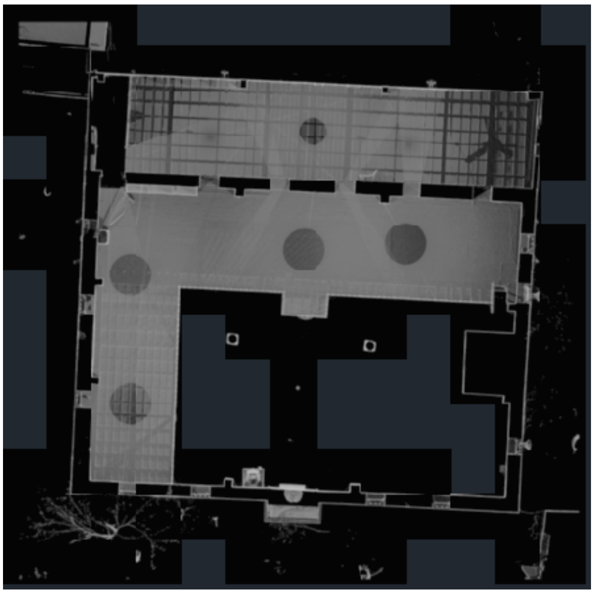

Figure 7. Orthophoto of ground floor plan

Figure 8. Orthophoto of west frontage

Figure 9. Orthophoto of east frontage

Figure 10. Orthophoto of south frontage

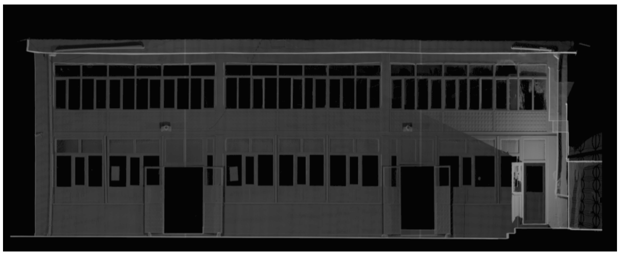

Figure 11. Orthophoto of north frontage

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

3.1. Documentation of Material Deteriorations on the Facades

When the facades are investigated, it is seen that the most frequent material deterioration seen is the surface contamination depending on the air pollution. This problem is followed by intervention with mortar, mossing, material loss, deformation, plaster and paint spalling, and cracks respectively from most to least (“Fig. 12”).

Figure 12. Legend regarding the material damage layouts

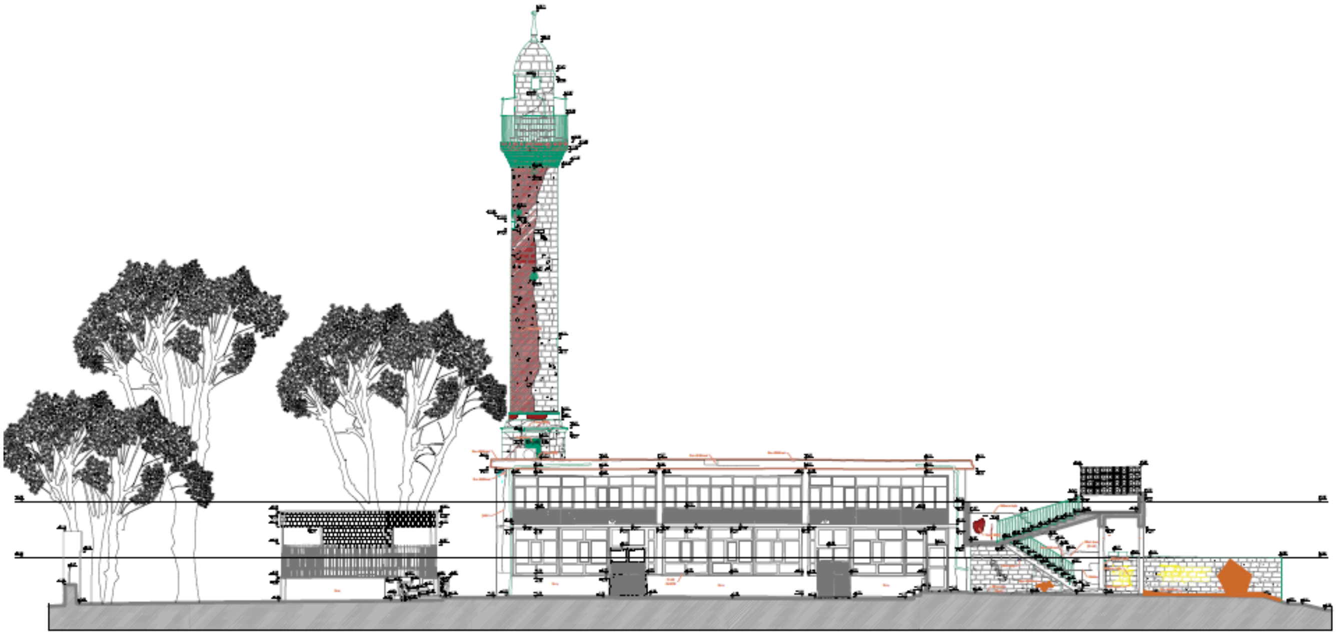

Figure 13. North frontage material damage layout

Plaster spalling, cracks, material loss, surface contamination, deformation, paint spalling were found on the north frontage (''Fig. 13'').

Intense deteriorations were observed on the South frontage and deformation, intervention with mortar and mossing problems are seen. Although there is interventions with cement-added mortar partly on the stone surfaces close to the ground elevation, as well as surface contaminations are seen (''Fig. 13'').

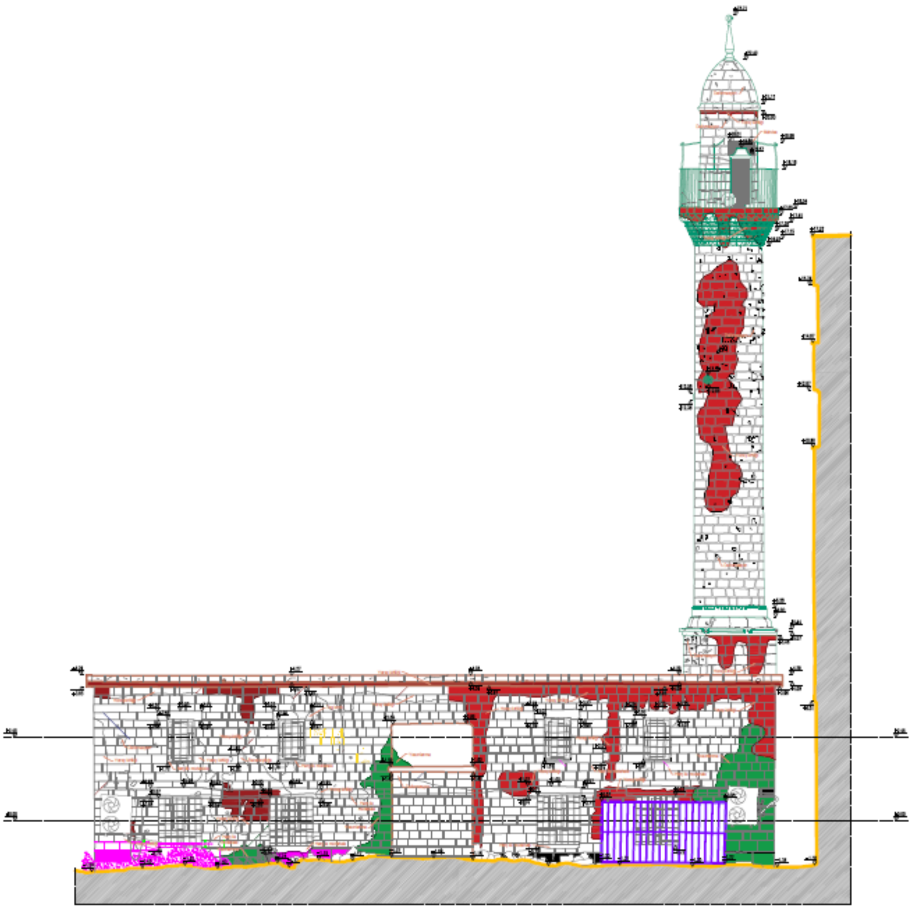

Figure 14. South frontage material damage layout

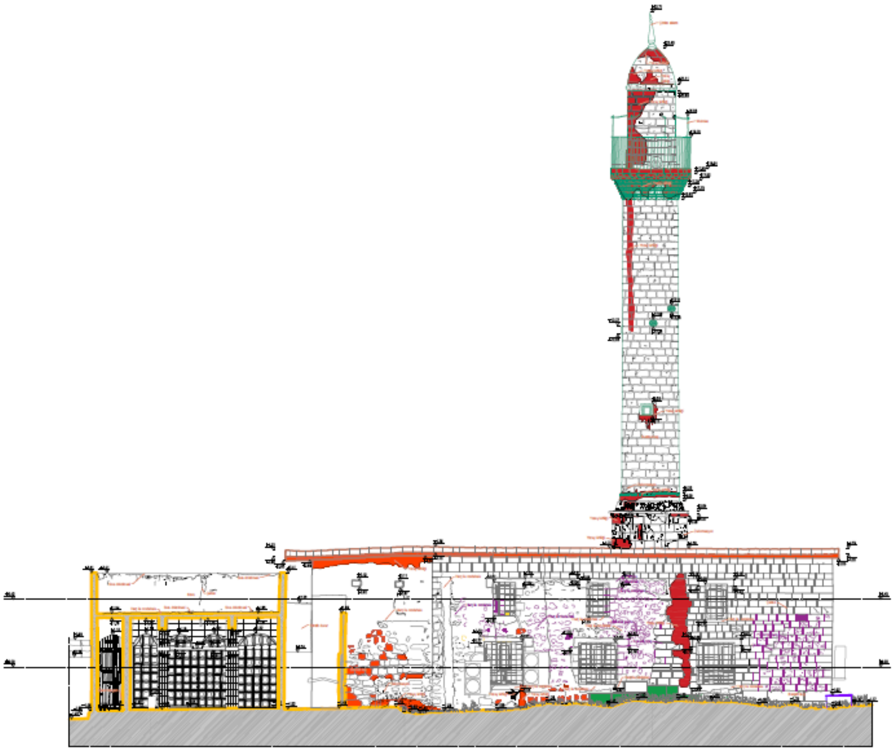

Figure 15. West frontage material damage layout

Problems of deformation, plaster spalling, intervention with mortar, surface contamination, material loss, mossing, and cracks were found on the west frontage. Intense surface contaminations, primarily the material losses, wear and fractions on the stone surface were observed (''Fig. 13'').

Intense deteriorations were observed on cut stone and basalt stone surfaces on the facade located on the east frontage, and problems of surface contamination, deformation, cracks, intervention with mortar, and mossing are seen. Besides, jerry-built attachments such as the electric cables, and sound installations are also present on the facade (''Fig. 13'').

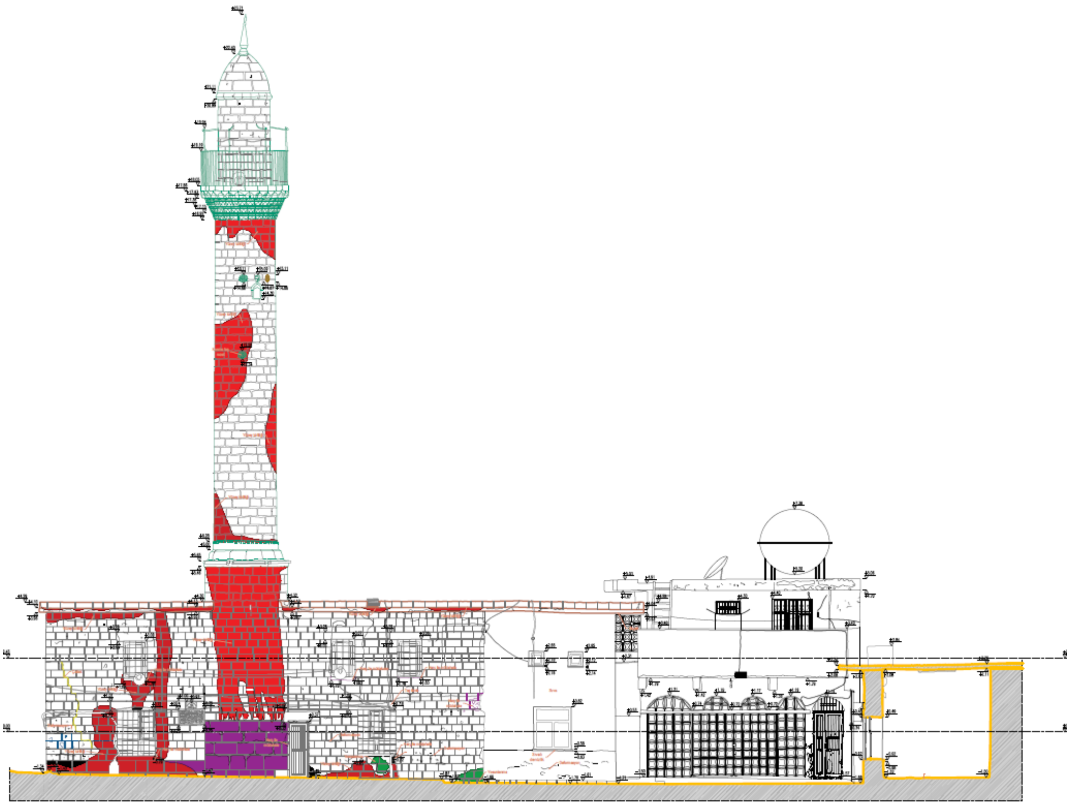

Figure 16. East frontage material damage layout

4. DISCUSSION

The aim of the study is to analytically document the material deteriorations that occur on the facades by combining the data obtained from the observational determination of the building with the data obtained by terrestrial laser scanning. As a result of the study, it has been seen that the terrestrial laser scanning method and the use of orthophoto images can be used as a base in the creation of the drawings of the plans and facades of the building, instead of the traditional methods that require long and laborious measurements, and this method provides great savings in terms of time and effort. This result obtained in the study supports studies showing that it is sufficient to produce architectural drawings (sections and plans) from orthophotos produced from laser scanning data (Comert et al., 2012; Gabriele et al., 2010; Mol et al., 2020; Stober et al., 2018; Meroño et al., 2015; Rawashdeh, 2013; Perfetti et al., 2019; Rawashdeh,2013; Widartono & Fitri Rawashdeh,2013; Widartono & Fitri, 2016; Perfetti et al., 2019).

In addition, when the drawings obtained from the orthophotos and the data obtained from the observational determinations are combined as a result of the study, it is seen that the material damages can be easily mapped. This result; Widartono & Fitri (2016) and Corso et al. (2017), drawings produced from orthophoto images obtained by various methods from terrestrial laser scanning and observational detection data are similar to the results of studies showing that various types of deterioration in the stone facades of structures can be easily mapped.

Another result obtained in the study is that orthophotos obtained from the data obtained by terrestrial laser scanning save time and effort in documenting material problems and architectural documentation. This finding confirms the finding of Yılmaz et al. (2007) that orthophoto images obtained from terrestrial laser scanning data are easier, more precise, and save time compared to classical methods in documenting material problems and architectural drawings.

In the study, it was determined in the findings about which types of material deterioration were seen on the facades of the building; the most common material degradation is surface contamination in the form of a gray layer. This finding in the study supports the finding in the literature that the most common material deterioration in stone structures in the world is surface pollution within the scope of Şanlıurfa Kışla Mosque (Ambrosini et al., 2019; Comite et al., 2017; Comite et al., 2020; Corvo et al., 2010; Falchi et al., 2019; Gibeaux et al., 2018; Graue et al., 2013; Ivaskova et al., 2015; Rovella et al., 2020; Vidorni et al., 2019; Vidal et al., 2018; Webb, 1992).

5. CONCLUSION

In the study, facade drawings were made by using orthophotos produced from the data obtained from terrestrial laser scanning as a base, and material damage maps of the building were obtained by processing the observationally detected material deteriorations on the facades. As a result of the study, it has been determined that the most common material deterioration in stone facades is surface pollution, as in stone structures in many countries. In this context, in order to determine the causes of surface pollution in the building and the source of the dirt (air pollution, traffic, user effects), it is necessary to carry out various experimental researches in the building in subsequent researches.

Once the cause of the surface contamination has been determined, a decision should be made to use either the cleaning technique or the combined techniques. The type of dirt and its relationship with the surface, the correct definition of the stone surface-patina relationship, and the separation of dirt and patina are matters of expertise. In addition, the state of preservation of the stone surface to be cleaned, the construction technique, and the neighboring materials should also be taken into account in the making of the decisions. Different methods should be used for building stone surfaces and decorated stone surfaces, different stone surfaces and impurities. One or more of the techniques such as washing with atomized water, absorbing clays and pulp compression, gels, controlled sandblasting, micro sandblasting, precision mechanical cleaning with small hand tools, laser cleaning should be applied on the test surfaces on the structure, and the surface erosion and the effectiveness of the method should be tested.

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Author contributions

Lale Karataş; Methodology, data collection, writing **Aydın Alptekin;** Control. **Murat Yakar:** Editing the manuscript

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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