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The Evolutıon Of Deterıoratıon In Hıstorıcal Buıldıngs After Restoratıon: The Example Of Hagıa Elenı Church (Konya-Turkey)

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Introduction

Restoration works are extremely important when attempting to preserve the structural integrity of cultural heritage. While the achievement of these studies can securely transfer the heritage to future generations, the opposite situation can accelerate the development of deterioration and lead to critical mistakes that can impact the static status of the monuments (Hatır, İnce & Bozkurt, 2022). Therefore, it is vital to develop scientific approaches to achieve the solution of problems in restoration works with the multidisciplinary cooperation of experts (architects, geological engineers, civil engineers, chemists, biologists, etc.). The first stages of these studies are to determine the types and origins of deterioration and the determination of the material properties utilized in the monument. The aim is to determine the mineralogical composition, petrographic, durability, and index-strength properties of the materials employed in the historic structure and also their relationship with the deterioration development, which will form the basis of the restoration methods to be implemented. One or more of the appropriate restoration treatments (consolidation, filling, cleaning, etc.) will be chosen according to the level of deterioration obtained from this stage. In cases that cannot be saved with restoration treatments or where part of the monument is destroyed, completion works will be required. In these cases, completion works that are not compatible with the original material of the historical structure will accelerate the deterioration processes as well as damaging the visual aesthetics of the monument (Hatır, İnce & Bozkurt, 2022).

This study investigated the process of deterioration that occurred after the restoration works, in the case of Hagia Eleni Church (Konya-Turkey). During the restoration work, it was observed that the completion work was not suitable for the original mortar and therefore increased the deterioration process in the building stones. For this purpose, the types of deterioration in the monument were analysed and their origin was investigated. In addition, the index-engineering properties of the original building stones were determined by laboratory studies and their relationship with the deterioration processes was discussed.

Study Area

Eleni Church is located in the Sille region, about 8 km from Konya city center. The church, which has rooms carved into the rock in its courtyard, has three naves (Figure 1). The middle nave of the monument is held up by four piers and covered with a dome. There are

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friezes of Jesus Christ, Mary and the apostles on both the piers and transition elements of the dome. The apse and the main space of the church are separated by a wooden sermon pulpit which is subsequently decorated with plaster. The church, which is unique in the region due to the frescoes and planning scheme, has undergone many repairs throughout history. The monument, whose inscription claims that it was last repaired in 1833, was restored in 2012.

Figure 1. General View of Hagia Eleni Church

Materials And Method

ln this study, Sille stone, which is widely employed in the construction of cultural stone heritage in the Konya region was investigated. This type of stone was also used in the construction of the church of St. Elena, and was extracted from ancient quarries excavated in volcanic rocks located 8 km northwest of Konya. For the experimental phase of this study, 30x30x30 cm uniform rock samples were collected from the ancient quarries. Dry density (ρ_d) and porosity (n) values of the index properties of Sille stone were determined according to the methods recommended in TS EN-1936 (2010), although the P-wave velocity (Vp) value was occurred according to the methods in ASTM E494 (2010). After the P-wave velocity, measurement of the rock was taken three times and then the mean value was obtained as the P-wave velocity value. The capillary water absorption value of the samples was determined in accordance with the methods specified in TS EN-1925 (2000). Uniaxial compression strength (UCS), one of the strength parameters of Sille stone, was determined according to TS EN-1926 (2007). UCS tests were carried out on cube samples with a side length of 7 cm. In the test, the loading rate was implemented within the limits of 0.5-1.0 MPa/s. The test was then carried out on 5 samples and the mean value of these tests was determined based on the UCS value of Sille stone. The Schmidt hammer hardness (SHR) values of the rock were determined according to the method recommended in ASTM D5873 (2014) which was implemented with the use of an L-type hammer. While determining the SHR value of Sille stone, measurements were performed at 10 different points of the sample and then the mean measurement was calculated. To determine the SHR value, the deviations of more than seven units from the average were subtracted.

The remaining measurements were again given a mean value and this value was therefore used as the SHR value of Sille stone. In order to determine the mineralogical composition and textural properties of Sille stone, thin sections were prepared according to the recommended method in TS EN-12407 (2019) and then examined under a polarizing microscope. The types of deterioration in Hagia Eleni Church were identified based on the definitions in the ICOMOS (2008) dictionary.2012.

Results And Discussions

Petrographic Properties of The Samples

Macro examination of Sille stone displays plagioclase, biotite and quartz phenocrysts floating in a light-dark pink-coloured paste (Figure 2). The mineralogical composition of the rock includes 32% plagioclase, 16% biotite, 16% plagioclase microlites, 10% quartz, 3% opaque minerals and 23% volcanic glass. Due to the mineralogical composition, this can be defined as "plagiodacite" according to Streckeisen (1979). It was determined that Sille stone has a hypo crystalline porphyritic texture in thin sections. In addition, Hatır (2020) defined the rock as dacite based on the anaoxide values.

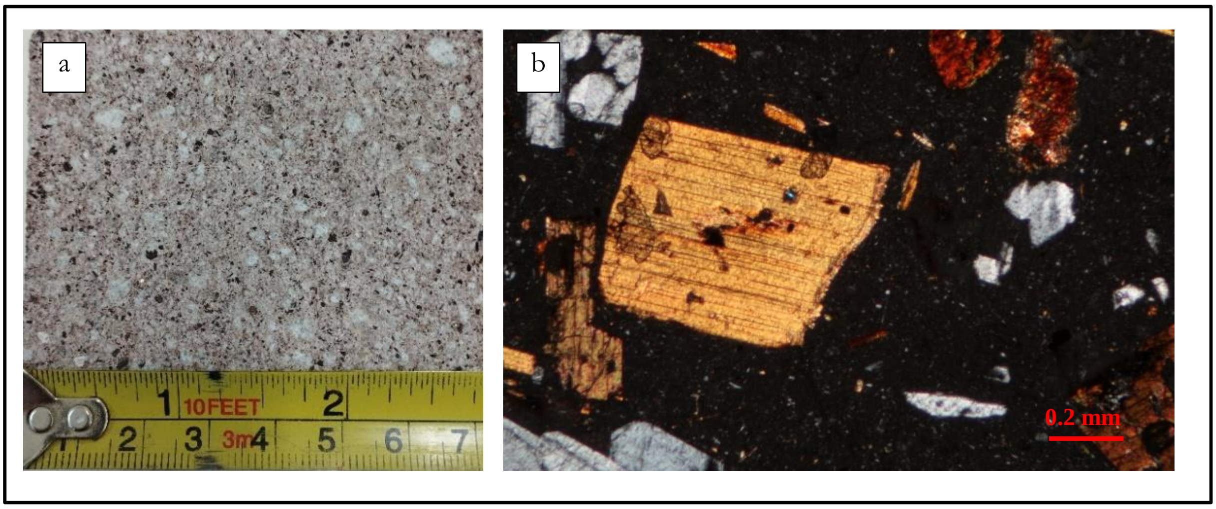

Figure 2. The appearance of Sille stone (a) macroscopic image, (b) microscope image (Crossed polars)

Indexes-Strength and Weathering Properties of The Samples

The index-strength and weathering properties of Sille stone are presented in Table 1. Among the index properties, porosity, dry density and P-wave velocity values are 5.55%, 2.35 g/cm^3 and 3.75 km/s, respectively. According to NBG (1985) porosity classification, Sille stone is classified as high porosity rock. The capillary water absorption value of Sille stone is 5.41 g/m^{2}s$^{0.5}$ and is in the lower absorption rock group according to the classification of capillary water absorption value of rocks in Snethlage (2005). SHR and HL values of the surface hardness are 37.30 and 651.57 respectively. The UCS value of the rock was determined as 58.30 MPa.

The variation of Sille stone against freeze-thaw (F-T) and salt crystallization (SC) processes from atmospheric events have been studied by a variety of different researchers (Zedef & et al., 2007; İnce, 2013; Fener & İnce, 2015; Saydan, Keskin & Kansun, 2020). The dry weight loss (DWL) value of Sille stone, which is widely preferred to determine the alteration in rocks after rapid degradation tests, was determined as 0.144% for the F-T test and 35.77% for the SC test (Zedef & et al., 2007; İnce, 2013). Considering the DWL values, it can be suggested that the SC process is more influential in the deterioration of Sille stone.

Table 1. Index-Strength and DWL Values of Sille Stone

	index				strength			weathering	
Sample	n	C	ρ_d	Vp	SHR	HL*	UCS	F-T$_{DWL}$**	SC$_{DWL}$***
	%	g/m^{2}s^{0,5}	g/cm^3	km/s			MPa	%	%
Sille Stone	5.55	5.41	2.35	3.75	37.30	651.57	58.30	0.144	35.77

* Obtained from İnce & Bozdağ, 2021 ** İnce, 2013 *** Zedef & et al., 2007

Types of Deterioration Observed in The Monument

Restoration implementations of historical buildings are significant for the maintenance of the monuments. However, in cases where the implementations are not based on scientific grounds, the deterioration processes in monuments may accelerate and their structural integrity may be at risk to larger threat. In this study, the deterioration observed in the monument after the restoration works carried out in the church of Hagia Eleni in the Sille region of Konya in the year 2012 is evaluated. After the restoration of the monument, a moist area was examined due to capillarity (Figure 3a). This occurred because the drainage lines were not designed and implemented during the restoration works.

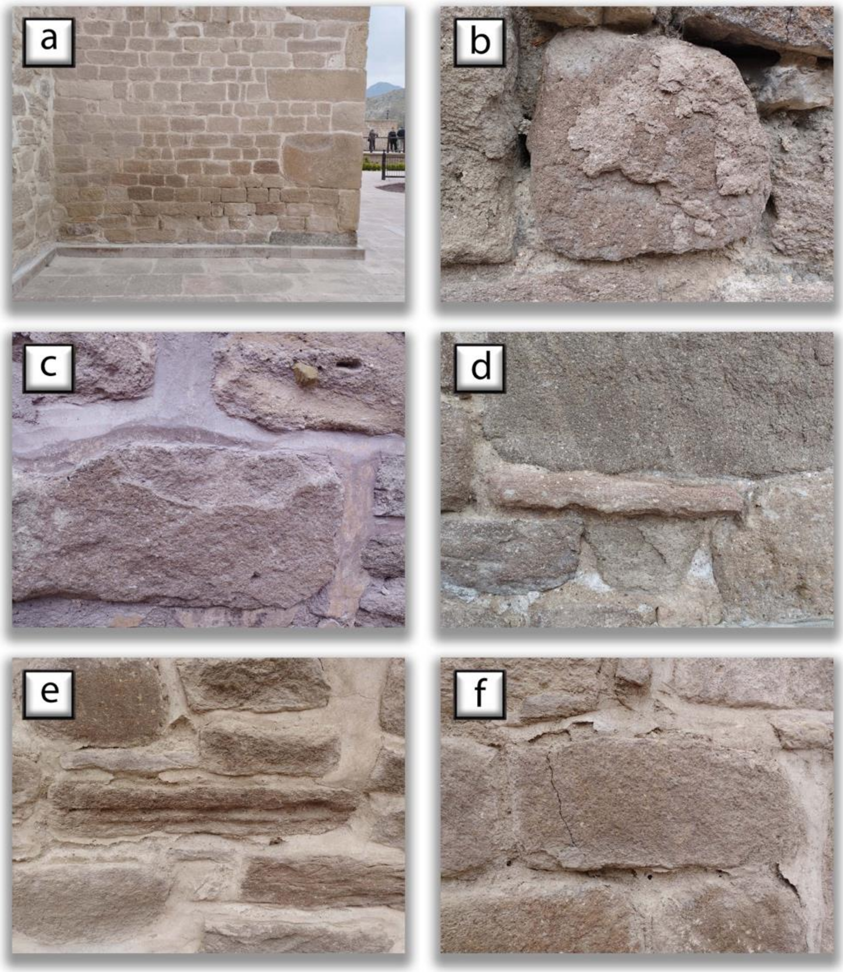

Figure 3. Types Of Deterioration Observed on The Building Stones of Hagia Eleni Church; a) Moist Area, b) Flaking, c) Contour Scaling, d) Efflorescence, e) Differential Erosion, f) Crack

Moist area development caused widespread flaking (Figure 3b), contour scaling (Figures 3b and 3c) and efflorescence deterioration (Figure 3d) in the capillary zone. The sensitivity of the rock to freeze-thaw, wetting-drying and salt crystallization processes were the main factors in the development of these processes. In other parts of the church, differential erosion (Figure 3e) type developed concerning the textural characteristics of Sille stone. As a result of the deterioration processes of the monument, cracks (Figure 3f) were observed in the building stones whose strength properties were weakened as a result. In addition, the metal railings of the building's windows have been corroded over time and have caused subsequently staining type on the building stones.

The fact that the mortar used in the restoration of the monument was incompatible with the original material was a factor in the acceleration of the deterioration process. In this process, the chemical additives in the mortar dissolved with the effect of capillary water. In the next stage, the increase in temperature caused the intensification of efflorescence development around the mortars in the capillary region. In the following stage of this cycle, the mortars gradually lost their binding properties and in places disintegrated (Figure 4). As a result of the increase in the contact surfaces of the water with the building blocks in the missing joint areas, the degradation mechanisms became more influential and increased the development of deterioration.

Figure 4. Mortar losses in monument joints

Conclusion

While restoration work should contribute to the conservation of monuments, in some cases the implementation of incorrect procedures can accelerate the deterioration process. This study examined this process in the case of Hagia Eleni Church and the findings are provided below.

• Failure to examine the fundamental causes of deterioration processes in historical buildings before restoration reduces the success rate of the implementations. Failure to design the drainage infrastructure in Hagia Eleni Church resulted in a moist area throughout the monument.

• Not utilizing the original building materials of the monument in restoration implementations may accelerate the deterioration processes. The mortar used without determining the original properties of the structure caused deterioration starting from the joint areas of the monument.

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