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# The Deterioration Problems Observed in the Natural Building Blocks of Saint George Church in Diyarbakır Province

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**Abstract**
In this study, the deterioration problems in the building blocks of the Saint George Church in Diyarbakır was observed and its causes were investigated. Physicomechanical, biological and chemical degradations occurring in the building are classified using international criteria and each type of degradation is explained by giving examples through visual examination. Physicomechanical deteriorations such as fractures, cracks, abrasions, and honeycomb weathering are mostly seen in the structure of the stones. Black crust and salt accumulations caused by biological and chemical effects were also observed.The aim of this study is to examine the causes and types of degradation observed in the building blocks of the Saint George Church and to draw attention to the initiation of the works to take precautions by emphasizing the necessity of conservation and restoration processes in the building. We think that this study can be a resource that can be used in the conservation practices of other stone structures in Diyarbakır.
**Keywords:** Diyarbakır, Saint George Church, natural stone, decay

## 1. INTRODUCTION

Saint George Church, which is one of the eight churches that can reach today in the Suriçi region in Diyarbakır province, has been the subject of this study due to its feature of being one of the important historical structures in the province. The church, also known as the Black Pastor, was built as a whole with the city walls on the hard cliff overlooking the Tigris valley at the northeastern end of İçkale, which follows Viran Tepe in the Central Sur District. (Figure 1).

It is written that the building was built before Christianity and then converted into a church. However, the view that it has a Byzantine structure outweighs. It is estimated that the church was built in the 4th or 5th centuries [1]. In the floor plan of Saint George Church, an additive bath structure from the Seljuk period can be seen. When this attached building is viewed from the outside, the building material and dimensions reflect the characteristics of its period [2]. The three-nave and basilica planned church joins the city walls in the east direction. Saint George Church consists of an entrance (narthex), the central area covered with an elliptical brick dome, and the vault in the east direction against the apse (Figure 1). The plan is not the same on either side of the apse, where the rocks are carved. The plan is not the same on either side of the apse, where the rocks are carved. It is the only building without a courtyard among the historical churches in the city wall. St. George's Church is in the "Turkey Cultural Heritage" list. After the restoration work carried out in 2006, Saint George Church continues to function as an art gallery. It hosts various artistic events throughout the year.

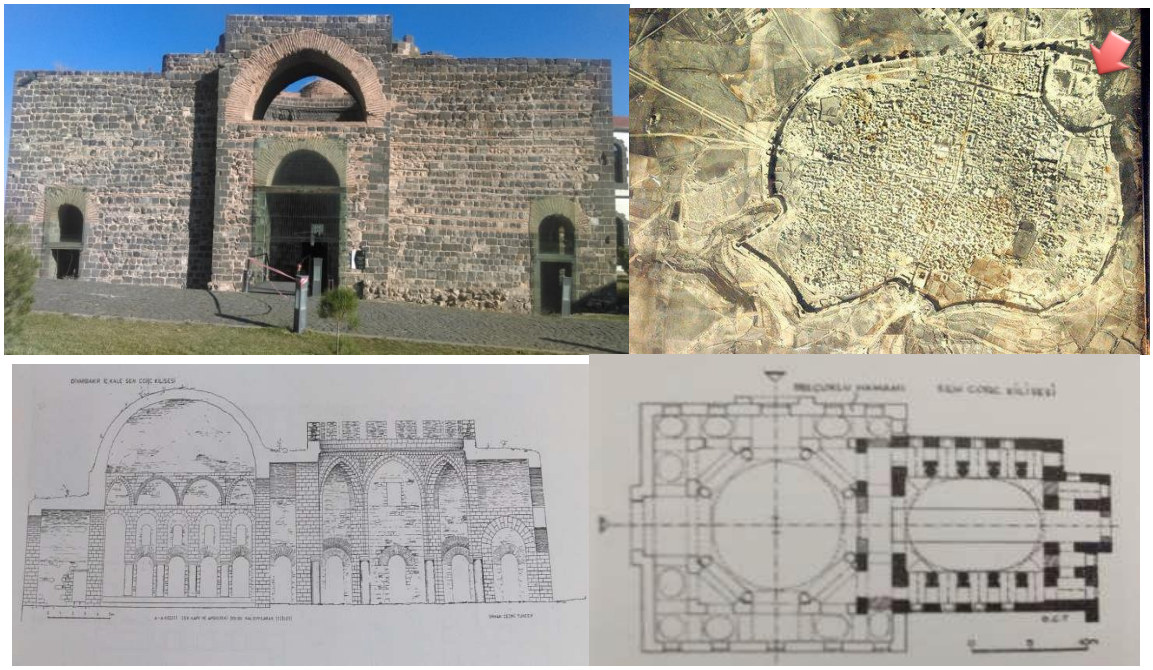

Figure1.Saint George Church front view (top-left); its location in the city wall (top-right) and the church section and its plan [2].

## 2. MATERIAL and METHOD

In this study, the building stones that form the architectural materials of the Saint George Church in Diyarbakır were examined and their damages were observed and evaluated. Thus, the deterioration problems of the stones used in the construction of the church was determined and compared with the previously published literature information [3,4,5,6,7]."Observation-analysis-synthesis method" was used during the research. A two-stage methodology was used as a work plan. In the first section, observations were made to the location of the building, and detailed photos were taken and the first weathering map was created. In the second stage, the studies on determining the degradation status of the building were completed by evaluating the first weathering status map and also re-examining the photographs.

Like other historical buildings in Diyarbakır, basalt stone was used as the main building stone by following the traditional construction technique in Saint George Church. Basalt arch legs are supported with rounded limestone columns. This is followed by a domed section with a pillar in front of it. This section, which was added to the building during the Artuklu period, was also used as a bath during the Seljuk period.

It is observed that limestone is preferred in the construction of basalt stone columns and bases in the church. This main building system is complemented by bearing walls in masonry construction, supported by wooden beams. Lime binder (Horasan mortar) was used in the building with a wall thickness exceeding 1 meter.

## 3. TYPES of DECOMPOSITION in the BUILDING BLOCKS of SAINT GEORGE CHURCH

Stone structures are generally exposed to degradation due to factors related to environmental conditions, and over time they lose their physical-mechanical properties [8]. Knowing the factors causing the deterioration of the stones is very important in terms of being an initial guide in determining future protection and repair works.

As a result of the observations made in the Saint George Church, which is the subject of the study, physical deterioration is generally observed, as well as biological and chemical deterioration. The location of the building, the properties of the ground on which it is

located, the physical properties of the stones used in the building and the mistakes made while using the building are the main factors.

Physical degradations such as cracks, cracked, joint discharges, abrasions, honeycomb weathering etc. are the most common on church walls. Chemical degradation such as black layers, salts, and various types of biodegradation have been also observed.

Mechanical degradation was observed as a result of the building's losing its qualities due to reasons such as heat expansions as well as the structure sitting on the ground over time. It is observed that when the tensile or compressive strength is exceeded, as a result of the changes in their behavior, cracks occur due to slippage and pressure in the building elements (Figure 3).

Figure 2. Cracks observed on the wall of the western interior facade of the Saint George Church (left) and a 20 cm fracture occurring in the lower part of the column at the entrance.

"Honeycomb", which is a type of degradation caused by external atmospheric conditions and erosion, look like honeycombs or sea sponges. This type of change, also called alveolar decay, is a decay frequently observed on the surfaces of church basalt building blocks (Figure 3).

Figure 3. The formation of honeycomb type weathering on the north interior wall of the Saint George Church is seen.

"The repeated abrasion effect of feet" is common in thresholds and it is done by constant human movement on the courtyard floorings (Figure 4). It is manifested by the disappearance of a large part of the original surface of the stone more than 5 cm.

Figure 2. 8 cm abrasion (left) on the wall in the southern interior of Saint George Church (left) and abrasion occurring in the threshold in front of the entrance door

The stones are weakened and dissolved over time due to various reasons, especially as a result of washing. The mortars separated from the stones cause the joints to drain. Gaps of various depths and sizes are formed between the stones. It manifests itself as "joint discharge" in some of the building walls (Figure 5). It is believed that it accelerates other decays as it also causes the floor and ceiling surfaces of the stones to be exposed. Joint discharge is seen more clearly in the buttresses located on the outer facade of the entrance door of the church.

Figure 5. Examples of the type of decomposition related to 10mm joint discharge (left) occurring on the eastern exterior of the church and joint discharge occurring on the south outer facade.

Unfortunately, "Graffiti" observed in almost all historical buildings can be seen in the architectural elements of the Saint George Church. It is a very common visitor behavior that "scratching" the stone surface by drawing it with a pointed object.The Saint George Church was damaged by scratching (Figure 6).

Figure 6. Graffiti was created by visitors by drawing with a pointed object in the limestone columns of the church (left). Metal objects was fixed on basalt wall stones (Right).

“Surface contamination”, defined as the accumulation of foreign matter that does not belong to stone, develops depending on the environmental climate conditions. Especially in the industrial areas, besides the gases released to the atmosphere for various reasons, fuel consumption and exhaust gases that increase due to the long winter season cause intense air pollution and cause pollution on the buildings.Polluted compounds such as gas and particulate nitrogen, sulfur, nitrate (NO2) in the atmosphere accumulate on the surface over time. This accumulation on the stone surfaces reacts in a humid environment formed by snow and rain and has an acidic effect and accelerates the abrasion by converting calcium carbonate (lime) into gypsum (gypsum), one of the main components of the stone. Such degradation, the main factors of which are the humidity and temperature in the environment, develops as a result of a chemical interaction. This situation is observed both on the outer and inner walls of the Saint George Church (Figure 7).

Figure 7. Black layer formation on the columns of Saint George Church (left) and black layer formation under the western wall of the church can be evidently seen.

Another type of degradation that is frequently seen in open-air structures is “erosion”. It develops with the freeze-thaw cycle for many years and as a result it manifests as loss of material on the stone surface (Figure 8).

Soluble salt crystallization mechanism is frequently seen in building stones. Salts that settle in stone pores with the help of moisture turn into solid-state with the increase of heat and begin to crystallize [9]. In cases where the increased volume of salt particles cannot reach the surface of the stone, it stays in the pores and increases its volume, which causes micro-cracks in the stone. These capillary cracks turn into large cracks with the effect of other factors over time, leading to stone breaks [10]. "Salt accumulation" was found on some walls of the church. Because the basalt building Stones has a porous structure, the salts are brought to the surface with water. In the next stage, salt crystals form on the surface during the evaporation of water. Salt crystallization on the stones of the church walls causes damage to the joint fillings (Figure 8). Besides, as the stones at the bottom of the wall absorb water and raise it to the upper sections, molten salts are carried to the upper surface of the wall [11]. With the increasing temperature, the evaporation of water from the rock surface and the formation of hard crusts with the melting salts accumulating on the stone surface [12] are also observed in some walls of the church.

Figure 8. Surface erosion (left) is observed on a brick wall on the western interior of the church and salt accumulations is also observed on the wall of the church south interior facade.

In the building stones of the church, besides physical and chemical deteriorations, biodegradation problems were also observed. Biological degradation has been observed in the stones used in historical buildings as a result of the harmony of the microchemical genetic structure with the effect of the physicochemical reactions in the environmental conditions [13,14].

The basalt stones used in Saint George Church have high capillarity due to being porous structure. In this way, the stones remain constantly moist by absorbing the water, which creates an environment suitable for the development of algae between the joints. It is a consequence of the more abrasions of the stones used in the walls of the building close to the ground. This moisture changes the color of the stones since it causes accumulation and contamination on the surface. In addition to the algae formed on the floor stone surface in the courtyard, high plants that developed in the walls of the church and the joint cavities have been observed to affect the stones negatively with the physical pressure they have with their roots and the oxalic acid effect they secrete over time (Figure 9).

In addition to the humidity-related deterioration caused by the dome of the church made of bricks and the lack of maintenance, plant developments are also observed. This vegetation on the dome was caused by the insufficient insulation of rainwater [15].

In addition to the damage of birds to architectural building stones, the insects create holes in the stones with mechanical effects such as scraping and climbing. They also cause chemical degradation with high levels of organic acids [16, 17, 18, 19]. Also, it is determined that bacteria that hold nitrogen from organic matter and atmosphere also accelerate the degradation by accumulating on the weathered stone surfaces. Due to the accommodation of birds in some parts of the building and especially the substances contained in pigeon droppings, it causes degradation by showing acidic properties. The accumulation of bird droppings observed in different parts of the building may cause material loss and color change over time (Figure 9).

Figure 9. Different types of vegetal colonization are observed on church walls and flooring: Moss development (top-left) between the paving stones on the courtyard floor; herbaceous plants (top-right) formed between the wall joints; herbaceous plant formation on the wall destroyed by algae (bottom-left) occurring in the ground stones in the courtyard of the church.

Color change was also observed in some building blocks of Saint George Church (Figure 10). It is known that this color change may develop by decomposition of the minerals contained in the basalt stone as well as due to biological factors [20]. It can be said that the reason for the color change seen in the stones in the church is the iron oxide origin that occurs on the surface as a result of the meeting of the stone minerals with water.

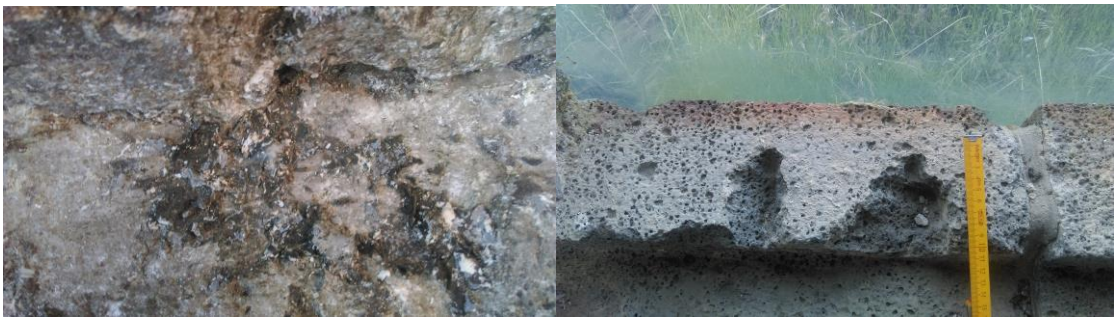

Figure 10. Biodegradation caused by bird droppings on the ground at the south facade of the courtyard of Saint George Church (left). Color change is observed in basalt stones on the church walls (right)

## 4. RESULTS

It is an important factor to know the characteristics of the original building stones and the sources that cause deterioration in historical structures must be known to do reliable restoration works. The acquisition of this background is the most important first step towards determining the choice of protection and repair practices. In many repairs carried out today, proper protection methods have not been applied since the properties of the building block are not sufficiently recognized and the types of degradation cannot be determined correctly. We hope that this research will be a guide to the relevant units to prevent such problems and to apply the protection programs prepared in line with the repair of historical structures more consciously.

It is believed that the physicomechanical damages observed in the carrier system in Saint George Church, as in other historical structures in the city wall in Diyarbakır, are caused by sitting on the ground [15, 21]. It is not difficult to predict that the vegetation in the brick dome of the building will increase over time and cause the collapse of the walls.

Damages observed on the stones are caused due to the physical, chemical, and biological factors. These factors can be effective on their own and help each other and accelerate the decay process. Physical weathering separates the rocks into small pieces, increasing the surface area. Chemical degradation also helps physical degradation while changing the structure of minerals.

Each type of deterioration is different from each other and requires a different protection method and application. Therefore, how to eliminate the damaging factors can be determined by comprehensively classifying the type of degradation. For this reason, it is important to use the terminology accepted in the international platform while grouping the types of degradation in the common language of the studies to take appropriate protection measures.

As a result of the visual examinations in Saint George Church; physical degradation such as fractures, cracks, joint discharges, abrasions, honeycomb weathering, chemical degradation such as black layers, salting, and biological degradation such as herbaceous plants, bacterial alterations have been found.

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