Selçuklu Medeniyeti Araştırmaları Dergisi (SEMA)
Journal of Seljuk Civilisational Studies (JSCS)
ISSN: 2651-2602
DOI: 10.47702/sema.2023.28

Yıl: 8 Sayı:8 2023 | Araştırma Makelesi / Research Article | E-ISSN: 2548-0367

Damage Types and Repair Techniques in Seljuk Period Stone Architectural Monuments: Konya Alaaddin Mosque

Şerife Sümeyra GÜREL

Master's Student, Necmettin Erbakan University, Institute of Science, Architecture, Konya, Türkiye,
s.sumeyragurel@gmail.com

Mustafa DERELİ

Assistant Professor, Necmettin Erbakan University, Faculty of Fine Arts and Architecture, Architecture, Konya, Türkiye,
mustafa.dereli@erbakan.edu.tr *(Sorumlu Yazar/Corresponding Author)*

Article Info

Article History

Received: 25.08.2023
Accepted: 12.11.2023
Published: 31.12.2023

Anahtar Kelimeler:

Natural Stone, Types of Damage in Building Materials, Repair Techniques, Alaaddin Mosque, Seljuk Architectural Heritage.

ABSTRACT

In order to determine the correct conservation and repair techniques for stone architectural monuments, it is necessary to determine the types of damage that occur in the stone. The determination of damage types is directly related to the factors that cause damage. In this study, the factors that cause deterioration in natural stones and the types of weathering were classified through literature research. Through the literature review, different repair techniques depending on the type of deterioration were examined. A field study was carried out based on the data obtained from the research conducted within the scope of the study. Alaaddin Mosque, one of the Seljuk period stone architectural monumental buildings located in Konya city centre and whose restoration works have been completed in recent years, was selected to be examined. In order to obtain information about the conservation and repair activities applied in the building, the archive of Konya Regional Directorate of Foundations, which carried out the restoration works, was utilized. The repairs applied to the building were documented by on-site inspection, observation and photography techniques. The observations made during the fieldwork draw attention to the deterioration of the stone materials after the repair activities. In this direction, the deterioration was photographed and classified using the data obtained from the literature. The factors causing the deterioration were analysed and discussed in the results section.

Selçuklu Dönemi Taş Mimari Eserlerinde Hasar Türleri ve Onarım Teknikleri: Konya Alaaddin Cami

Makale Bilgileri

Makale Geçmişi

Geliş: 25.08.2023
Kabul: 12.11.2023
Yayın: 31.12.2023

Keywords:

Doğal Taş, Yapı Malzemelerinde Hasar Türleri, Onarım Teknikleri, Alaaddin Cami, Selçuklu Mimari Mirası.

ÖZ

Taş mimari anıtlar için doğru koruma ve onarım tekniklerinin belirlenebilmesi için taşta meydana gelen hasar türlerinin tespit edilmesi gerekmektedir. Hasar türlerinin belirlenmesi ise hasara neden olan faktörlerle doğrudan ilişkilidir. Bu çalışmada, doğal taşlarda bozulmaya neden olan faktörler ve ayrışma türleri, yapılan literatür araştırması ile sınıflandırılmıştır. Literatür taraması ile bozulma türüne bağlı olarak farklı onarım teknikleri incelenmiştir. Çalışma kapsamında yapılan araştırmalardan elde edilen verilere dayanarak bir saha çalışması gerçekleştirilmiştir. Konya kent merkezinde bulunan ve son yıllarda restorasyon çalışmaları tamamlanan Selçuklu dönemi taş mimari anıtsal yapılarından Alaaddin Camii incelenmek üzere seçilmiştir. Yapıda uygulanan koruma ve onarım faaliyetleri hakkında bilgi edinmek amacıyla restorasyon çalışmalarını yürüten Konya Vakıflar Bölge Müdürlüğü arşivinden yararlanılmıştır. Yapıya uygulanan onarımlar yerinde inceleme, gözlem ve fotoğraflama teknikleri ile belgelenmiştir. Saha çalışması sırasında yapılan gözlemler, onarım faaliyetleri sonrasında taş malzemelerde meydana gelen bozulmalara dikkat çekmektedir. Bu doğrultuda bozulmalar fotoğraflanmış ve literatürden elde edilen veriler kullanılarak sınıflandırılmıştır. Bozulmaya neden olan faktörler analiz edilmiş ve sonuçlar bölümünde tartışılmıştır.

Atıf/Citation: Gürel, Şerife Sümeyra – Dereli, Mustafa. "Damage Types and Repair Techniques in Seljuk Period Stone Architectural Monuments: Konya Alaaddin Mosque". *Selçuklu Medeniyeti Araştırmaları Dergisi (SEMA)* 8 (Aralık 2023), 1-21. https://doi.org/10.47702/sema.2023.28

INTRODUCTION[1]

Throughout history, stone has been recognized as a symbol of strength and durability. For this reason, it has been preferred especially in monumental structures that are planned to be permanent. The main reason for the widespread use of stone material in buildings is that various natural stones are available in many regions and can be easily obtained.

The physical and mechanical properties of stones with different geological origins also differ. Not every stone is suitable for use as a building material. The area of use of each building material differs. It is important to determine the properties of the stone correctly in the selection of materials suitable for the area of use and purpose.

Building materials lose their strength in the face of time and environmental factors and undergo physical, chemical and biological degradation. These deteriorations occur depending on the material's texture, pore ratio, etc., and environmental conditions. Correct determination of the causes, types and distributions of the degradation of the material is the most important stage in determining the protection and repair methods to be applied.

Stone architectural monuments, which have an important place in the world cultural heritage, are damaged by various factors and disappear over time. The conservation of buildings is important in terms of ensuring cultural continuity. The aim of this study is to examine the types of deterioration that occur in stone architectural structures, the factors that cause deterioration and conservation-repair methods and to evaluate them on a sample area.

METHOD

In this study, necessary literature searches were made through databases in order to determine the types of deterioration and repair techniques in stone materials. Within the scope of the field study, researches were carried out on stone architectural monuments in Konya province where conservation and repair works have been carried out recently. Alaaddin Mosque, located in the central Selçuklu district of Konya, whose restoration works were completed by Konya Regional Directorate of Foundations, was selected as the study area. The stone architectural monument was examined by utilizing the archive of Konya Regional Directorate of Foundations. The findings obtained by on-site observation and photographic documentation techniques are evaluated in the results section.

1. Factors Causing Degradation (Decomposition) in Natural Stones

Stone structures are damaged as a result of various factors as part of their natural processes. These damages occur as a result of site selection, soil properties, structural system design errors, poor workmanship, faulty material selection, natural disasters, long-term natural factors, and various anthropogenic factors. [2] Physical, chemical and biological degradation (decomposition) occurs in stones exposed to one or more of these factors. These deteriorations can cause permanent damage by damaging the integrity of the structure. It is important to identify the factors causing damage and to classify the types of weathering in order to apply the correct protection and repair techniques. [3]

---

[1] The archive of Konya Regional Directorate of Foundations, General Directorate of Foundations, Ministry of Culture and Tourism of the Republic of Turkey was utilized in the research. We would like to thank them for their assistance.

[2] Hayriye Gülçin Kara, *Tarihi Yığma Yapıların Taşıyıcı Sistemleri, Güvenliğinin İncelenmesi, Onarımı ve Güçlendirilmesi* (İstanbul: İstanbul Teknik Üniversitesi Fen Bilimleri Enstitüsü, 2009), 91.

[3] Mehmet Ergün Hatir et al., "Deep Learning-Based Weathering Type Recognition in Historical Stone Monuments," *Journal of Cultural Heritage* 45 (September 1, 2020), 193–203; Ali D. Öcal - Murat Dal, *Doğal Taşlardaki Bozunmalar* (İstanbul: Mimarlık Vakfı İktisadi İşletmesi, 2012), 25.

Degradation of stone materials occurs as a result of physical, chemical, and biological processes that progress in a mutually reinforcing manner. [4] The factors causing weathering can be classified as internal causes (lithology, mineralogical and petrographic properties, chemical composition, etc.) and external causes (atmospheric effects, natural disasters, air pollution, etc.) due to various environmental conditions. [5]

1.1. Internal Factors Causing Deterioration

These are factors arising from the structural properties of the stone material or the structure in which the material is used. The location of the structure, soil properties, faulty material selection and use, lithology, mineralogical and petrographic properties, chemical structure and physico-mechanical properties of the stone are the internal causes of segregation.

• Location of the Building: The location of the building (slope, hollow, coastal, etc.) may cause it to be more affected by different climatic conditions. For example, floods experienced in buildings located in pits or on the coast may cause more intense damage to the stone material. [6]

• Ground Properties of the Structure: Factors such as inhomogeneity, loose structure, low strength of the ground on which the building sits may cause movements such as rotation, settlement, etc., in the structure. As a result of these movements, decomposition, cracking and fragmentation of the stone material occur. In addition, the location of the building on a fault line also leads to damage or complete collapse of the building. [7]

• Incorrect Material Selection and Use: Stones that are not suitable for use as building materials start to deteriorate rapidly in the face of environmental factors. In addition, mistakes such as extracting the stone to be used as building material from the quarry with the use of explosives, crushing it as a result of incorrect strikes during the processing process, using the stone without resting, and laying stones with different properties together can cause deterioration in the material. [8]

• Lithology of Stone: The fact that natural stones have different geological origins is a determining factor in their structural properties. According to experimental studies on stones with different formations, metamorphic and igneous stones are more durable than sedimentary rocks due to their structural properties and textures. For this reason, they are less affected by environmental factors and deterioration occurs more slowly. [9]

• Mineralogical and Petrographic Properties of Stone: The type of minerals that make up the stone, particle size, bonding strength, crystal structure, intercrystallite binders, gap distance, etc., determine its durability and behaviour against water. Minerals prone to weathering accelerate the deterioration process of the stone. For example, silicates are more affected by acids than calcium

[4] Dario Ambrosini et al., "The Potential of Optical Profilometry in the Study of Cultural Stone Weathering," Journal of Imaging 5/6 (June 1, 2019), 60.

[5] Binnaz Vural - Murat Dal, "Mimari Yapılardaki Doğal Taş Malzeme Bozunmalarının Nedenleri ve Türleri," *Mimarlık Bilimlerinde Güncel Konular-2022*, (2022), 261.

[6] Saadet Tuğba Şirikçi, *Tarihi Eserlerde Yapı Malzeme Cinslerinin Araştırılması ve Korunmaları İçin Alınacak Önlemler* (İstanbul: Haliç Üniversitesi Fen Bilimleri Enstitüsü, 2013), 10; Uğur Hasbay - Sibel Hattap, "Doğal Taşlardaki Bozunma (Ayrışma) Türleri ve Nedenleri," *Bilim ve Gençlik Dergisi* 5/1 (2017), 23–45.

[7] Hasan Ali Mahrebel, *Tarihi Yapılarda Taşıyıcı Sistem Özellikleri, Hasarlar, Onarım ve Güçlendirme Teknikleri* (İstanbul: İstanbul Teknik Üniversitesi Fen Bilimleri Enstitüsü, 2006), 36; Zeynep Ahunbay, *Tarihi Çevre Koruma ve Restorasyon* (İstanbul: Yem Yayın, 2019), 38.

[8] Murat Dal, "Trakya Bölgesi Tarihi Yapılarında Kullanılan Karbonatlı Taşların Bozulma Nedenleri," *Vakıflar Dergisi* 34 (2010), 47–59.

[9] Serdar Aydın, *Taş ve Ahşap Mimari Anıtların Bozulma Nedenleri ve Onarım Teknikleri* (İstanbul: Yıldız Teknik Üniversitesi, 1987), 13.

carbonates and cause deterioration in the stone. [10]

The strength of the stone depends on its crystal structure and properties. The fine crystal structure of the stone increases the interlocking power and provides strength to the stone. As the crystal size increases, the interlocking power decreases, and the stone starts to decompose more quickly. Another important factor affecting weathering is the intercrystallite binding agent. Easy dissolution of the binder causes the stone to deteriorate more quickly. For example, silicon dioxide (SiO_2) binders are the most durable, while clay binders dissolve rapidly when they come into contact with water and cause weathering of the stone. [11]

• Chemical Structure of Stone: Stone and the minerals that make up the stone contain various chemical components. These components can react with water and cause different deterioration in the stone. Chemical components such as potassium chloride (KCl), calcium chloride (CaCl), sodium chloride (NaCl) dissolve away from the stone when they react with water and create voids in the internal structure. Chemical compounds such as calcium sulphate ($CaSO_4$), on the other hand, when reacted with water, can expand in volume to the point of bursting the stone and accelerating bacterial growth. [12]

• Physico-Mechanical Properties of Stone: Physical properties of the stone such as density, water absorption capacity, porosity (void ratio) determine the stone's response to environmental conditions. As the density value of a stone increases, the stone gets tired more quickly. The density of building stones is 2.5 g/cm^3 on average. The preference of stones that are not suitable for this value as carrier system material may cause damage to the structure and material. [13]

Porosity, size and distribution of the stone directly affect its behavior in freezing and thawing events. Stones with high porosity have high permeability and the stone passes the liquid into its structure more easily. Water penetrating into the stone progresses in the cavities and causes degradation. Especially in low temperature regions, freezing of water in the pores increases the internal pressure of the stone and causes decomposition. [14]

1.2. External Factors Causing Deterioration

The external causes of deterioration in stone materials are natural or human-induced environmental factors. These are natural disasters, climatic and atmospheric factors, biological factors, and various anthropogenic factors.

• Natural Disasters: Natural disasters such as earthquakes, floods, landslides, erosion, typhoons are among the factors that cause damage to historical buildings. As a result of earthquakes, liquefaction, slipping, etc., in the ground, the structure settles and cracks occur in the stone material. [15]

• Climate and Atmosphere Effects: The main atmospheric factors that cause deterioration of stone material are temperature change, sun rays, wind, humidity and precipitation and air pollution. Stone exposed to these factors undergoes physical and chemical decomposition and causes various plants and organisms to grow on the stone surface.

[10] Aydın, *Taş ve Ahşap Mimari Anıtların Bozulma Nedenleri ve Onarım Teknikleri*, 13.
[11] Aydın, *Taş ve Ahşap Mimari Anıtların Bozulma Nedenleri ve Onarım Teknikleri*, *14*; Murat Dal - Seyhan Yardımlı, "Taş Duvarlarda Yüzey Bozunmaları," *Kent Akademisi Kent Kültürü ve Yönetimi Dergisi* 14/2 (June 15, 2021), 428–451.
[12] Öcal - Dal, *Doğal Taşlardaki Bozunmalar*, 43.
[13] Aydın, *Taş ve Ahşap Mimari Anıtların Bozulma Nedenleri ve Onarım Teknikleri*, 15.
[14] Öcal - Dal, *Doğal Taşlardaki Bozunmalar*, 43.
[15] Öcal - Dal, *Doğal Taşlardaki Bozunmalar*, 46.

Seasonal temperature changes cause expansion and contraction depending on the types of minerals contained in the stone. Disintegration occurs with the weakening of the bonds between minerals. In addition, freezing and thawing of water or moisture in the stone as a result of temperature difference can cause physical deterioration such as cracks, fragmentation, etc. [16]

Water and moisture are the main factors influencing the initiation of physical, chemical and biological weathering. Water can enter the stone and cause the weathering of minerals, dissolution of transported salts, changes in pH and the growth of various biological organisms on the stone surface. [17] Stone directly exposed to water as a result of precipitation loses its strength over time when it reaches water absorption saturation. In addition, water and moisture coming into the structure from the ground leads to the dissolution of salts on the surface and the formation of efflorescence and mosses. [18]

Particles such as dust, smoke and sand hit the stone material with the effect of strong winds and cause accumulation on the surfaces, leading to deterioration of the stone appearance and contamination. In addition, water particles hitting the surface with the force of the wind during rainy periods enter through cracks and holes in the stone, causing the wall to get wet and the cracks to deepen. [19]

Solar radiation leads to heat and moisture exchange between the atmosphere and the structure, causing damage to the material. [20] The heating and colour-changing ultraviolet (UV) and infrared rays in the sun's rays are absorbed by the surfaces they hit, increasing the surface temperature, and causing the expansion of building materials. In addition, as a result of chemical changes in the stone exposed to harmful rays, colour change and stains occur on the surface. [21]

Harmful gases such as carbon dioxide, carbon monoxide, sulfur dioxide, etc., released into the atmosphere as a result of industrialization and artificial activities increase the amount of N_2O, CO, H_2, SO_2 and some hydrocarbons in the fresh air. These gases cause deterioration in building materials in dry or rainy environments. [22]

• Biological Factors: Plant organisms such as plants, algae, fungi, bacteria, lichens, etc. and animals such as birds, spiders, etc. are biological factors that cause degradation in stone. Various animals and insects create holes and cavities on the stone surface with various chemicals they secrete or by scraping. [23]

---

[16] Aydın, *Taş ve Ahşap Mimari Anıtların Bozulma Nedenleri ve Onarım Teknikleri,* 22; Dal-Yardımlı, "Taş Duvarlarda Yüzey Bozunmaları."

[17] Jizhong Huang et al., "Study of Internal Moisture Condensation for the Conservation of Stone Cultural Heritage," *Journal of Cultural Heritage* 56 (July 1, 2022), 1–9.

[18] M. Sami Döndüren et al., "Tarihi Yapılarda Görülen Hasar Türleri," *Selçuk Üniversitesi Sosyal ve Teknik Araştırmalar Dergisi* 13 (2017), 45–58.

[19] Mustafa Dereli et al., "Yapıların Cephe Kaplama Malzemelerinde Hasar Oluşturan Etkilerin Tespiti ve Çözüm Önerileri - Konya Ptt Hizmet Binası Örneği," *Selcuk University Journal of Engineering ,Science and Technology* 6/3 (September 1, 2018), 445–460.

[20] Dario Camuffo, "Deterioration Processes of Historical Monuments," In Studies in Environmental Science 30 (1986), 189–221.

[21] Dal - Yardımlı, "Taş Duvarlarda Yüzey Bozunmaları"; Dereli et al., "Yapıların Cephe Kaplama Malzemelerinde Hasar Oluşturan Etkilerin Tespiti ve Çözüm Önerileri - Konya Ptt Hizmet Binası Örneği."

[22] Hacera Bayık - İdris Bedirhanoğlu, "Tarihi Yapılarda Kullanılan Doğal Taşlarda Bozunmalar," *Farklı Yaklaşımlarla Madenler ve Değerli Taşlar*, (2022), 495–511.

[23] Ayşin Konak et al., "Açık Hava Koşullarında Sergilenen Taş Eserlerde Bozulma - Bozunma Süreçleri ve Koruma Yöntemleri," *Adıyaman Üniversitesi Sosyal Bilimler Enstitüsü Dergisi* 0/42 (December 29, 2022), 194–226.

Bacteria, algae, fungi and lichens on the stone surface develop rapidly especially in humid environments and cause dissolution and oxidation of the stone with the acids they secrete. Mosses that grow on rough and moist surfaces take the moisture of the stone, take root and settle on the stone. [24]

• Anthropogenic Factors: Humans directly or indirectly cause damage to historic buildings. Misuse, neglect, abandonment, application of wrong repair techniques, public works, tourism activities, wars, fires, vandalism, traffic, air pollution, etc. Historic buildings are damaged, and materials deteriorate as a result of various human activities and factors caused by these activities. [25]

2. Types of Degradation (Weathering) in Natural Stones

The deterioration of stones is caused by the combination of one or more of the deterioration factors mentioned in the study due to material structure and various environmental factors. The physical, chemical, and biological processes that initiate the degradation progress by supporting each other and cause the material to decompose. Decomposition types are classified in Table 1.

Table 1. *Segregation Types* [26]

PHYSICAL SEGREGATION	CHEMICAL SEGREGATION	BIOLOGICAL SEGREGATION
Crack - Fracture Formation	Black Layer Formation (Contamination)	Mossification
Honeycombing	Salinization (Flowering)	Bacteria Formation
Abrasion (Erosion)	Leafing	Algae Formation
Joint Discharge	Scour and Microkarst Formation	Fungus Formation
Part Breakage	Crust Throwing	Lichen Formation
Cuts and Scratches of Anthropogenic Origin	Corrosion and Rust Stain	Herbal Elements
Graffiti		

2.1. Physical Deterioration

Physical degradation is the mechanical decomposition of the stone as a result of the weakening of the bonds of the minerals in the internal structure of the stone without any change. These decompositions are observed as crack-fracture formation, honeycombing, abrasion, joint discharge, fragment breakage and human-induced cuts-scratches and graffiti. [27]

• Crack - Fracture Formation: Cracks occur in the structure as a result of earthquakes and various ground problems, settlements that cause shrinkage, freezing - thawing, thermal expansion, etc.,

[24] Gregory A Pope et al., "Geomorphology's Role in the Study of Weathering of Cultural Stone," *Geomorphology* 47/2 (2002), 211–225; Aydın, *Taş ve Ahşap Mimari Anıtların Bozulma Nedenleri ve Onarım Teknikleri*.
[25] Ahunbay, *Tarihi Çevre Koruma ve Restorasyon*, 50.
[26] Sara Khooshroo et al., "İstanbul Süleymaniye Camii Taş Yüzeylerinde Tespit Edilen," (2017); Öcal - Dal, *Doğal Taşlardaki Bozunmalar*, 73.
[27] Öcal - Dal, *Doğal Taşlardaki Bozunmalar*, 71.

in the internal structure of the stone. As a result of factors such as the growth of capillary cracks, vandalism, earthquakes, etc., the cracks in the stone grow throughout the stone and lead to fractures. [28]

• Honeycombing: The soft parts of the stone melt as a result of factors such as freezing-thawing, temperature difference, etc., causing loss of texture, while the hard parts protect themselves, resulting in honeycomb or sea sponge-like deterioration on the stone surface. [29]

• Abrasion (Erosion): Erosion, which occurs on the stone surface as a result of natural or anthropogenic factors in the form of softening, rounding and thinning of the stone cross-section, is the loss of soft-lined material. Abrasions in millimetric or centimetric dimensions are seen as flaking, crumbling and disintegration following the cross-section of the stone. [30] While physical abrasion occurs as a result of thermal stress, water pressure, salt crystals and biological factors, chemical abrasion occurs as a result of factors such as dissolution, oxidation, melting, etc., as a result of the stone's interaction with water. [31]

• Joint Discharge: The mortars that hold the stone masonry together can dissolve and separate from the stones due to their structural properties or various environmental factors. As a result of the spillage of the joints, the sensitivity of the stones that remain empty around them to environmental factors increases and their degradation processes accelerate. In addition, as a result of the weakening of the connection between the stones forming the wall surface, there is a loss of parts in the structure and its strength decreases. [32]

• Fragment Detachment: It is the separation of a part of the stone from the main mass as a result of structural or environmental factors. As a result of these factors, the internal pressure in the structure of the stone causes cracks. As a result of the development of cracks, the weaker part of the stone is pushed away from the main mass. [33]

• Anthropogenic Cuts and Scratches: Many activities carried out consciously or unconsciously by humans cause damage to structures and deterioration of materials. Factors such as inappropriate use of a building for its function, improper repair and neglect damage the structure, while events such as breaking and pouring, scratching and cutting applied to stone material damage the material and cause it to deteriorate by being affected more quickly by environmental factors. [34]

• Graffiti, one of the damages caused by people to historical buildings, is the painting of stone surfaces with materials such as paint, ink, etc. These paintings applied to stone surfaces are very difficult to clean. Deterioration of the material may occur in cleaning with the use of chemicals or abrasion method. [35]

2.2. Chemical Degradation

Chemical degradation is the changes that occur in the internal structure of the stone as a result of various climatic and atmospheric factors. These changes develop as hydration, hydrolysis, oxidation

[28] Bayık - Bedirhanoğlu, "Tarihi Yapılarda Kullanılan Doğal Taşlarda Bozunmalar"; Öcal - Dal, *Doğal Taşlardaki Bozunmalar*, 74.
[29] Dal - Yardımlı, "Taş Duvarlarda Yüzey Bozunmaları."
[30] Öcal - Dal, *Doğal Taşlardaki Bozunmalar*, 83.
[31] Şerife Özata, *Kapadokya Bölgesi Kaya Oyma Yapı Sorunları ve Çözüm Önerileri* (İstanbul: Yıldız Teknik Üniversitesi Fen Bilimleri Enstitüsü, 2015), 36.
[32] Hasbay - Hattap, "Doğal Taşlardaki Bozunma (Ayrışma) Türleri ve Nedenleri."
[33] MEB, "T.C. Millî Eğitim Bakanlığı İnşaat Teknolojisi Taş Bozulmalarını Teşhis Etme," (2013).
[34] Uğur Hasbay et al., "Doğal Taşlarda Görülen Fizikomekanik Hasarlar," *Bilim ve Gençlik Dergisi* 6/1 (2018), 1–13; Dal - Yardımlı, "Taş Duvarlarda Yüzey Bozunmaları."
[35] Dal - Yardımlı, "Taş Duvarlarda Yüzey Bozunmaları."

and dissolution. Chemical weathering is observed in the form of black layer formation, salinization, foliation, pitting and microkarst formation, crusting and rust stains. [36]

• Black Layer: It is the surface pollution that occurs on the stone surface as a result of atmospheric factors, especially humidity and temperature. Pollutant gases released into the atmosphere accumulate on the surface and form a crust layer. When the accumulated dirt reacts with water as a result of precipitation, it turns into lime ($CaCO_3$), which forms the components of the stone, and causes abrasions on the stone surface. [37]

• Salinization (Efflorescence): As a result of factors such as water, humidity, air pollution, various chemicals, etc., salts that settle in the structure of the stone accumulate in the stone. Depending on the ambient temperature, when the stone enters the drying phase, the water evaporates, but the salts cannot leave the stone and remain on the surface. Salt crystallizing on the stone surface changes the surface appearance and damages the joints. [38]

• Foliation: As a result of environmental factors, the stone surface swells and separates into layers of different thicknesses. In these layers, which look like leaves, the bond between the overlapping surfaces weakens and begins to fall off. [39]

• Pitting and Microkarst Formation: As a result of the dissolution of calcium carbonate in the structure of the stone under the influence of water, millimeter-sized gaps occur on the surface and the stone has a perforated appearance. In addition, wind and wave effects also cause pitting in the stone. [40]

• Crust Exposure: A crust layer is formed as a result of morphological changes in the stone or the adhesion and accumulation of environmental pollutants on the stone surface. The crust layer, which is mostly dark in color, tends to separate from the substrate in the later stages and may cause complete decomposition of the stone surface. [41]

• Corrosion and Rust Stain: In historical buildings, corrosion occurs as a result of oxidation of iron materials used in elements such as windows, doors, etc., with moisture in the air. Rust stains are formed on the stone surface as a result of the corroded iron material being washed away by precipitation. [42]

2.3. Biological Degradation

The settlement of various biological organisms and plants on stone surfaces and their growth as a result of atmospheric factors lead to weathering. Biological deterioration is observed as bacteria, algae, lichens, fungi, moss formation and plant growth on the stone surface.

• Bacteria: Bacteria that develop as cell colonies on stone surfaces cause microbiological degradation as a result of their chemical activities. Bacteria, which are mostly observed in blue-green

[36] Hasbay - Hattap, "Doğal Taşlardaki Bozunma (Ayrışma) Türleri ve Nedenleri."
[37] Hasbay - Hattap, "Doğal Taşlardaki Bozunma (Ayrışma) Türleri ve Nedenleri."
[38] Mustafa Yavuz Çelik - Ramazan Tığlı, "Afyon Yöresindeki Yüksek Gözenekli Yapı Taşlarında Su İtici Kimyasal Kullanılmasının Tuz Etkisinin Araştırılması," *Gazi Üniversitesi Mühendislik-Mimarlık Fakültesi Dergisi* 2018/2018 (April 6, 2018).
[39] Özata, *Kapadokya Bölgesi Kaya Oyma Yapı Sorunları Ve Çözüm Önerileri*, 35.
[40] Konak et al., "Açık Hava Koşullarında Sergilenen Taş Eserlerde Bozulma - Bozunma Süreçleri ve Koruma Yöntemleri."
[41] Kurtuluş Artık - Merdan Törehan Turan, "Karbonatlı Yapı Taşlarında Görülen Kimyasal Alterasyonlar," *Bilim ve Gençlik Dergisi* 6/1 (2018), 52–61; José Delgado Rodrigues, "Defining, Mapping and Assessing Deterioration Patterns in Stone Conservation Projects," *Journal of Cultural Heritage* 16/3 (May 1, 2015), 267–275.
[42] Hasbay - Hattap, "Doğal Taşlardaki Bozunma (Ayrışma) Türleri ve Nedenleri."

colors, make the stone surface slippery. Especially sulfate and nitrate bacteria cause black layer, spillage and blistering on the surface. [43]

• Mosses: Mosses, which grow on stones in moist and shaded areas, consist of many millimeter-thick microstructures on the surface. Depending on the presence of water in the environment, mosses, which are mostly green in color, keep the stone surface moist and cause decomposition on the stone surface with the enzymes they secrete. [44]

• Algae: They are microscopic organisms that grow rapidly in humid environments and form a biological layer on stone surfaces. Algae are observed in millimeter thicknesses on the stone surface in a dust-like structure. Although they mostly remain on the surface because they need sunlight for photosynthesis, in some cases they can reach deep into the stone and cause cracks in the stone. [45]

• Fungi: Fungi, which require organic tissue for their development, form on stone surfaces with the contribution of pollutants in the atmosphere. They are generally observed as yellow, red, orange-colored layers on stones, cause exfoliation on the surface and cause deterioration such as pitting, especially on carbonate stones. Fungi, which have a mutualistic lifestyle, also constitute the body of lichens. [46]

• Lichens: Organisms formed as a result of the coexistence of fungi and algae, are formed in the moist and shadow parts of the stone surfaces. Lichens secrete lichenic and oxalic acid and cause surface loss by crusting and pitting in the form of fragments. They also cause plant formation by accumulating soil in stones with sufficient organic matter. [47]

• Plants: Plants growing on the wall surfaces of buildings, especially between joints, cause cracks and splits in the stone material and cause degradation on the stone surface with the enzymes they secrete. Plants growing around the building cause superficial and internal pressure on the stone as a result of their roots reaching the foundation and the carrier system is damaged. [48]

3. Stone Protection and Repair Methods

In the realization of stone conservation works, first of all, survey studies should be carried out and the current situation should be determined. Determination of material properties; ultrasonic measurement, hardness measurement, compressive stress determination, etc. It is based on on-site studies and laboratory research on samples taken from the stone. [49]

Repair methods are determined as a result of the diagnoses made on the stone material. In the application of repair techniques, the cleaning process should be carried out with the method determined according to the characteristics and deterioration rate of the stone. If necessary, the stone should be repaired with water repellent and strengthening chemicals. If the deterioration is serious, the damaged area should be cleaned by stone decomposition and completed with material suitable for the

[43] Ayşe Dolar - Ebru Şebnem Yılmaz, "Kültürel Yapılarda Biyolojik Bozunma Mekanizmaları," *Elektronik Mikrobiyoloji Dergisi* 12/1 (2014), 1–19.
[44] Öcal - Dal, *Doğal Taşlardaki Bozunmalar*, 115.
[45] Öcal - Dal, *Doğal Taşlardaki Bozunmalar*, 111.
[46] Dolar - Yılmaz, "Kültürel Yapılarda Biyolojik Bozunma Mekanizmaları"; Vural - Dal, "Mimari Yapılardaki Doğal Taş Malzeme Bozunmalarının Nedenleri ve Türleri."
[47] Özata, *Kapadokya Bölgesi Kaya Oyma Yapı Sorunları Ve Çözüm Önerileri*, 38.
[48] Ali Akın Akyol et al., "Ankara Akköprü Arkeometrik Çalışmaları," *Ankara Araştırmaları Dergisi* 1/1 (2013), 1–19.
[49] Fevziye Aköz - Nabi Yüzer, "Tarihi Yapılarda Malzeme Özelliklerinin Belirlenmesinde Uygulanan Yöntemler," *IMO-1. İnşaat Mühendisliği Egitimi Sempozyumu* 6/7 (2009).

original stone. After the repair activities, the stone material should be maintained in certain periods. [50]

3.1. Stone Cleaning

Water washing, cleaning with chemicals, mechanical cleaning, abrasion by spraying, cleaning with heat or laser beams are used to clean stone surfaces. One of these methods is preferred depending on the contamination of the stone. It is important that the cleaning process is carried out slowly and carefully. Otherwise, fractures, cavities and pores occur on the surface and the stone is subjected to decomposition. [51]

• Washing: Water washing is primarily used for cleaning stone surfaces. Sudden over-wetting of the surface may cause stains and blooming on the surface. Spraying the water on the surface in the form of fine particles (smoke) ensures that the stone surface is washed evenly with little water and the stone is cleaned without causing deterioration. Detergent is sometimes used with water to clean the surface more easily and in a shorter time. In addition, wetting the paper pulp and sticking it to the surface is another cleaning method. [52]

• Chemical Cleaning: Some chemicals (acids and alkalis) are used when water has no effect on the dirt layer. In order to prevent damage to the stone, it is important that the appropriate substance is selected and applied by experts. In cleaning with acids, chloric, fluoric, etc. acids that will cause deterioration of the stone surface and binding material should not be used. Alkalis are generally used on calcareous stones with low resistance to acids. In cleaning with chemical substances, the time the chemical is impregnated on the surface is important. Also, the surface should be purified after the application. [53]

• Mechanical Cleaning: In mechanical cleaning, the surface is cleaned from dirt by sandpaper or sandblasting. Sanding method is not preferred much today as it causes abrasions on the surface. The sandblasting method is applied dry or wet in cases where there is heavy contamination on the stone surface. In this method where hard sands are sprayed on the surface, the grain size of the sand and the spray nozzle should be selected correctly to avoid pitting, cracks and stains on the surface. In aqueous sandblasting, the dust particles remaining on the surface are reduced. The surface should be washed after the sandblasting process is finished. [54]

• Cleaning with Laser Beams: Cleaning with laser beams is based on the principle of removing the stratified dirt from the surface by burning. The wavelength of the beams to be sent to the surface is determined according to the material properties and the thickness of the dirt layer. [55]

3.2. Consolidation and Protection of Stone

Consolidation is a method of injecting protective materials into the stone material in order to strengthen the degraded surfaces of the stone, increase its mechanical strength and establish a connection between the degraded and intact parts. Reinforcing agents are applied to the surface by brushing, spraying or dripping. If the substance does not penetrate deep into the stone, it is carried to

[50] Zeynep Sena Karkaş, *Tarihi Yapıların Cephelerinde Kullanılan Kagir Yapı Malzemelerinde Konservasyon Çalışmalarının İrdelenmesi ve Sistematik Bir Yöntem Önerisi* (İstanbul: İstanbul Teknik Üniversitesi Fen Bilimleri Enstitüsü, 2020), 28.
[51] Aydın, *Taş ve Ahşap Mimari Anıtların Bozulma Nedenleri ve Onarım Teknikleri*, 29.
[52] Aydın, *Taş ve Ahşap Mimari Anıtların Bozulma Nedenleri ve Onarım Teknikleri*, 31; Konak et al., "Açık Hava Koşullarında Sergilenen Taş Eserlerde Bozulma - Bozunma Süreçleri ve Koruma Yöntemleri."
[53] Aydın, *Taş ve Ahşap Mimari Anıtların Bozulma Nedenleri ve Onarım Teknikleri*, 39; Cengiz Çetin, "Taş Koruma ve Onarımında Temel Uygulamalar Ders Notları" (2023).
[54] Aydın, *Taş ve Ahşap Mimari Anıtların Bozulma Nedenleri ve Onarım Teknikleri*, 37.
[55] Çetin, "Taş Koruma ve Onarımında Temel Uygulamalar Ders Notları" (2023).

the surface under the influence of salt and water and loses its effect.

Reinforcing agents are of organic or inorganic origin. Inorganic substances are not affected by the sun and oxygen, but their resistance to mechanical effects is low because they form bonds between microcrystals. In addition, they can sometimes damage the stone by forming soluble salts. Organic reinforcements are sensitive to light and oxygen but are more elastic and resistant to mechanical stresses on the stone. They also provide protection by reducing the water absorption of the wall. Reinforcement provides protection for at least 10 to 20 years. Long lasting protection depends on regular maintenance and periodic reapplication of protective coatings. [56]

3.3. Grouting

Mortars used in stone-brick masonry in historical buildings are lime and Horasan mortars. Mortars deteriorate in the face of various environmental factors. Especially salinization occurring on damp wall surfaces causes decomposition in mortars. In re-plastering the joint gaps, mortars with high salt content should be cleaned and the gaps should be washed with pressurized water.

Today, various mortars are used in repair activities. Mortars are usually extruded through voids to delay weathering. However, this can lead to delayed drying and deterioration of the surfaces in contact with precipitation and water. Indented application of mortars through the voids also causes the same problems and reduces durability.

Horasan mortar, which is most preferred in stone building repairs, takes a red color due to the tile fragments in its content and is mostly used for visual purposes. It is a better decision to apply mortar by obtaining various mixtures by investigating factors such as physical, mechanical properties, water behavior, etc. The use of Portland cement in historical buildings is not recommended. [57]

3.4. Completing Missing Stones

The deterioration of historical buildings as a result of various factors may cause fracture, breakage or loss of stone material. The missing stones can be filled with natural or artificial stone. If the pieces broken from the main mass are small, they can be glued with products such as acrylic resin. However, strong adhesives or mortars should be used to join stones over a certain weight. For lost pieces, stones with the closest color, texture, hardness, etc. to the original stone should be preferred. For this purpose, it is important to research the original stone in the laboratory environment and reveal its properties.

In the event that a piece of the main mass of the stone or a stone close to the original cannot be found, artificial stones prepared by mixing various substances are used. Artificial stones are frequently preferred because they are easy to shape and economical. However, the surface of these stones is flat and flimsy. For this reason, they provide short-term solutions. [58]

3.5. Covering Stone Surfaces with Plaster - Paint

The surfaces are painted as a result of mistakes made during the construction or repair activities of stone architectural works. Problems such as the use of faulty materials, non-compliance with the project during restoration, the use of stones with different physical properties (color, texture, porosity, etc.) on the surface, etc. lead to different contamination. In cases where cleaning methods are

[56] Aydın, *Taş ve Ahşap Mimari Anıtların Bozulma Nedenleri ve Onarım Teknikleri,* 46; Ahmet Ersen, "Taş Korumada Son 20 Yıldaki ve Yenilikler," *Restorasyon ve Konservasyon Çalışmaları Dergisi* 10/10 (2013), 3–19.
[57] Aydın, *Taş ve Ahşap Mimari Anıtların Bozulma Nedenleri ve Onarım Teknikleri*, 57.
[58] Aydın, *Taş ve Ahşap Mimari Anıtların Bozulma Nedenleri ve Onarım Teknikleri*, 61.

insufficient, it is decided to paint the surfaces. After the necessary repairs are made on the surfaces, the painting process is carried out with silicate paints, which are generally preferred in accordance with the structure of the stone.

Plastering of walls is done, when necessary, just like painting. Before plastering the surface, the physical and chemical properties of the stone material should be investigated, necessary repairs should be made and plastered. The fact that the thin plaster applied on thick plaster is less durable ensures that the deterioration factors to which the surface is exposed are concentrated in this layer and the wall body is protected. This layer, called aging plaster, should be renewed regularly. [59]

3.6. Removing Moisture from the Wall

One of the factors that cause deterioration in stone material is the dampness of the wall surface. Drainage method is generally applied to prevent ground-borne moisture. Bringing the ground level of the building to the same level with the soil level or insulating around the building and drainage below the soil level reduces or completely prevents moisture in the wall. Apart from this method, pipes placed by drilling holes on the wall surface also provide evaporation of moisture.

Moisture in the wall leads to the formation of biological agents such as fungi, algae, lichens, plants, etc. on stone surfaces and biological decomposition takes place. By drying the moisture in the building, biological elements are also removed from the surfaces. Apart from this, the application of chemicals that kill biological organisms to the surface can cause damage to the wall. For this reason, it would be a better decision to plaster the walls by adding substances that kill organisms to the mortars. [60]

FINDINGS

In order to investigate the applications of conservation and repair methods in stone materials in historical buildings, Alaaddin Mosque in Selçuklu district of Konya province was examined by on-site observation and photography technique.

1. Alaaddin Mosque

Alaaddin Mosque is located on the mound called Alaaddin Hill in the city center of Konya (Figure 1). Built during the Seljuk State period, the mosque took its final form in 1220. According to the information in the inscriptions of the mosque, its construction started during the reign of Keykavus I and was completed during the reign of Alaaddin Keykubad.[61]

Figure 1. *Alaaddin Mosque location*[62] *and general view*

[59] Aydın, *Taş ve Ahşap Mimari Anıtların Bozulma Nedenleri ve Onarım Teknikleri*, 64.
[60] Aydın, *Taş ve Ahşap Mimari Anıtların Bozulma Nedenleri ve Onarım Teknikleri*, 66.
[61] İbrahim Hakkı Konyalı, Konya Tarihi (Konya:Yeni Kitap Basımevi,1964), 293.
[62] Konya Valiliği Çevre, Şehircilik ve İklim Değişikliği İl Müdürlüğü (Access 23 August 2023)

The polygonal mosque has a kufe plan (Figure 2). The courtyard to the north of the building contains the tomb of the sultans, a half tomb and tombs. The prayer section is located in the southern part of the building. The entrance to the mosque is provided from the gate on the east facade or from the courtyard on the north facade. There is a door opening to the courtyard from the place of worship. In the northern corner of the mosque, there is a brick minaret with 29 stone steps. On the walls of the mosque, stone slabs, bricks or stone bricks were used together. Marble is used on the north wall of the courtyard, interior columns, crown door decorations and some inscriptions.[63]

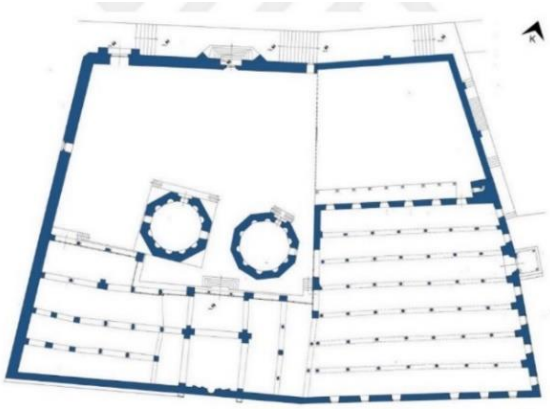

Figure 2. *Alaaddin Mosque Plan*[64]

1.1. Alaaddin Mosque Protection - Repair Activities

There is no information that the mosque was repaired during the Seljuk period, but various repairs were carried out during the Ottoman period. The repair inscription states that the mosque was in a dilapidated state in 1889 and was repaired by the order of Konya Governor Sururi Pasha, who was appointed by Abdülhamit II.[65] However, after these repairs, the mosque and mausoleum continued to suffer from dampness, especially due to rainfall. During the Republican period in 1945, 1957, 1966, 1975, 1975, 1978-1979, cracks and collapses occurred in the east and south walls, north and west walls and interior columns of the mosque. In 1945, the east and south walls of the mosque were demolished and rebuilt together with its cover and the upper cover was covered with lead. In 1978-79 restoration activities, wooden supports were added to the interior spaces. According to the researches, the main reason for the cracks in the mosque is that the water leaking from the ground and the vibrations caused by the traffic due to the fact that Alaaddin Hill is an intersection cause settlements in the structure.[66]

Alaaddin Mosque underwent a comprehensive restoration by the Konya Regional Directorate of Foundations between 2014 and 2020. Within the scope of the restoration works, 21 tombs belonging to the sultan family members were built in the courtyard and the mosque and sultan tombs were repaired.

[63] Burak Sevindi, Konya ve Çevresinde Yer Alan Vakıf Kayıtlarında Ulu Cami Olarak Geçen Camiler (Konya: Konya Teknik Üniversitesi, Lisansüstü Eğitim Enstitüsü, Yüksek Lisans Tezi, 2020), 37.

[64] Sevindi, Konya ve Çevresinde Yer Alan Vakıf Kayıtlarında Ulu Cami Olarak Geçen Camiler, 37.

[65] İbrahim Hakkı Konyalı, Konya Tarihi, 294.

[66] Remzi Aydın, Konya Alâeddin Camisi'nin Korunmasına Yönelik Girişimler (1889–1897), Turkish Studies 9/10 (2014), 33-60; M. Yaşar Kaltakçı – Süleyman Temizci, Konya Alaaddin Camii'nde Yapılan Zemin İyileştirme ve Temel Güçlendirme Çalışmaları ile Alaaddin Tepesinin Sorunları, İnşaat Mühendisliğinde Zemin Sempozyumu, (Konya: İnşaat Mühendisleri Odası İzmir Şubesi, 15 – 16 Kasım 1991), 15 – 25.

Low-pressure precision facade cleaning (Figure 3) and stone-brick rotting (Figure 4) were carried out where necessary on the stone surfaces of the mosque. The joints holding the stone and brick materials together were renewed with hydraulic lime added Horasan mortar (Figure 5). The natural stone pavements on the floors surrounding the building were renewed. Water damage to the stone walls was prevented by finishing the wall surfaces with capstone with stone roofs (Figure 6). The raised travertine pavements around the mausoleum were dismantled and the stone pavement was re-coated after the level was lowered. Low-pressure precision surface cleaning was performed on the marble columns in the interior (Figure 7) and the reinforcement belts and bracelets on the columns were sandblasted and painted with anti-rust (Figure 8). The mosque doors were surface cleaned and rehabilitated (Figure 9).[67]

Figure 3. *Facade cleaning carried out on the mosque's east facade and north courtyard facade rough masonry stones*

Figure 4. *Stone decomposition*

Figure 5. *Grouting with hydraulic lime added horasan mortar*

[67] Konya Vakıflar Bölge Müdürlüğü Arşivi.

Figure 6. *Addition of roofed capstone to rubble stone wall*

Figure 7. *Surface cleaned marble columns*

Figure 8. *Column headers after repair*

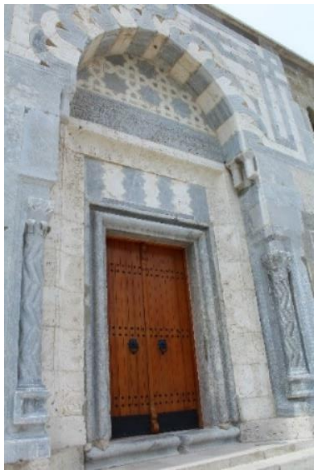

Figure 9. *North courtyard gate after repair*

1.2. Detected Deterioration of Stone Materials

Holes (Figure 10) were observed on different stone surfaces during observations in the area. The holes, which may sometimes be caused by the formation of the stone and sometimes by the effect of living organisms, may expand over time. Holes caused by the mineralogical formation of the stone are physically and chemically affected by exposure to atmospheric conditions. This effect will cause the stone to get sick, crumble and disintegrate. Filling the holes with material that is suitable for the properties of the stone and that will enable it to work together will prevent the damage from growing.

Figure 10. *Macropores that occur in the formation of the stone appear as holes on the surface*

On the surfaces of the stones, cavities with regular geometry (Figure 11), which are understood to have been made by human hands, are sometimes opened for assembly operations to the historical building. In some buildings, interventions such as scaffolding, air conditioning, electricity, etc. cable installations, plumbing and rain drainage pipe installations are made. While these interventions create undesirable images in the building, it is also possible that the cavities may cause the damage to increase.

Figure 11. *Man-made holes in the stone surface*

Fractures and cracks reflected on the surface of the stone may occur due to mechanical effects as well as physical effects such as expansion and contraction due to heat, swelling and contraction due to water, and exposure to pressure due to frost. Capillary cracks in the stone grow especially with the effect of freezing-thawing and appear as enlarged fractures and cracks as shown in Figure 12.

Figure 12. *Crack - fracture formations on the stone surface*

Expansion differences should be taken into account when combining different building materials. Otherwise, due to different elongation shortening coefficients, damage in the form of cracks occurs in the joint areas or in the material that cannot tolerate this physical phenomenon, as shown in Figure 13.

Figure 13. *Crack formation in joints due to thermal expansion*

The main cause of defects that appear as dark-colored soot on historic stone surfaces is air pollution from vehicles, industry and heating. Pollutant gases undergo chemical reactions on the surface of the stone and appear as the blackened surface shown in Figure 14-15.

Figure 14. *Defects caused by air pollution and exhaust gases*

Figure 15. *Abrasion on stone surface due to chemical effects*

Another formation seen as contamination on stone surfaces are biological formations such as moss, algae, lichen, bacteria, etc. They have a bad odor as well as a bad appearance. Biological elements that settle in the micro and macro pores on the stone surface cause the stone to look dirty as shown in Figure 16.

Figure 16. *Biological (Moss, Lichen etc.) formations on stone surfaces*

Damage in the form of abrasion on the stone surface is generally seen as the growth of capillary cracks over time and the abrasive effect of dust and particles carried by strong winds, as shown in Figure 17. Exfoliation due to the disease of the stone and large losses in volume may be the next type of damage.

Figure 17. *Abrasion on stone surface*

Traces made consciously or unconsciously on the surface of the sample structure damage the natural appearance of the stone (Figure 18).

Figure 18. *Pollution caused by paint and similar marking tools*

EVALUATION AND CONCLUSION

Although restoration works have been carried out on Alaaddin Mosque and maintenance and repairs have been carried out, damage and defects are still continuing on the structure. In addition to the determination of the damaging effects on our cultural assets, the determination and classification of the factors and types of decomposition that cause decomposition in stone materials will ensure the application of permanent correct protection and repair techniques. With this study;

- The effects that cause damage and defects in historical buildings vary according to the climatic conditions of the region, in this direction, the changing climatic conditions increase the temperature difference between day and night, precipitation and moisture remain within the structure through surface wetting and capillary paths from the ground and therefore damaged surfaces are formed,

- The Alaaddin Mosque, which was built on a mound with a filled ground, has ground settlement and heavy traffic around it, including rail systems, causing vibrations and mechanical damages to the structure,

- It has been determined that air pollution and the chemical effect of gases from vehicles cause visual pollution reflected on the whole structure. The fact that these problems are permanent reduces the effectiveness of the repairs made today.

Conservation and repair works on Alaaddin Mosque, our Seljuk period cultural asset, should be long-term. It is important to investigate the negative effects of urban heat islands created by changing climatic conditions on our historical buildings. In order to protect the building from the effects of water and moisture, it is important to drain rainwater and to establish drainage systems. In addition, prevention of air pollution will play an important role in the protection of stone surfaces after restoration. In this respect, there is a need to continue scientific studies in the field of conservation-repair of historical buildings and materials. Supporting the Directorate of Foundations and Municipalities as a society for the protection of our cultural assets will ensure that our cultural heritage will survive forever.

ACKNOWLEDGEMENTS

We would like to thank the Republic of Turkey Ministry of Culture and Tourism, General Directorate of Foundations, Konya Regional Directorate of Foundations, whose archive was utilized in the preparation of this article.

Author Contributions / Yazarların Katkısı: This article is a work with two-authors. The contribution of the aforementioned authors to the preparation of the article is equal. / Bu makale, iki yazarlı bir eserdir. Makalenin hazırlanmasına söz konusu yazarların katkısı eşittir.

Funding / Finansman: This research received no external funding. / Bu araştırma herhangi bir dış fon almamıştır.

Conflicts of Interest / Çıkar Çatışması: The author declare no conflict of interest. / Yazar, herhangi bir çıkar çatışması olmadığını beyan eder.

REFERENCES

Ahunbay, Zeynep. *Tarihi Çevre Koruma Ve Restorasyon*. İstanbul: Yem Yayın, 2019.

Aköz, Fevziye - Yüzer, Nabi. "Tarihi Yapılarda Malzeme Özelliklerinin Belirlenmesinde Uygulanan Yöntemler". *IMO-1. Insaat Muhendisligi Egitimi Sempozyumu* 6/7 (2009).

Akyol, Ali Akın Et Al. "Ankara Akköprü Arkeometrik Çalışmaları". *Ankara Araştırmaları Dergisi* 1/1 (2013), 1–19.

Ambrosini, Dario Et Al. "The Potential Of Optical Profilometry İn The Study Of Cultural Stone Weathering." *Journal Of Imaging* 5/6 (June 1, 2019). Https://Doi.Org/10.3390/Jimaging5060060

Artık, Kurtuluş - Turan, Merdan Törehan. "Karbonatlı Yapı Taşlarında Görülen Kimyasal Alterasyonlar." *Bilim Ve Gençlik Dergisi* 6/1 (2018), 52–61.

Aydın, Remzi. "Konya Alâeddin Camisi'nin Korunmasına Yönelik Girişimler (1889–1897)". *Turkish Studies* 9/10 (2014), 33-60

Aydın, Serdar. *Taş Ve Ahşap Mimari Anıtların Bozulma Nedenleri Ve Onarım Teknikleri*. İstanbul: Yıldız Teknik Üniversitesi, 1987.

Bayık, Hacera - Bedirhanoğlu, İdris. "Tarihi Yapılarda Kullanılan Doğal Taşlarda Bozunmalar." *Farklı Yaklaşımlarla Madenler Ve Değerli Taşlar*, 495–511. Https://Www.Researchgate.Net/Publication/366634359

Camuffo, Dario. "Deterioration Processes Of Historical Monuments." *In Studies İn Environmental Science* 30 (1986), 189–221.

Çelik, Mustafa Yavuz - Tıglı, Ramazan. "Afyon Yöresindeki Yüksek Gözenekli Yapı Taşlarında Su İtici Kimyasal Kullanılmasının Tuz Etkisinin Araştırılması." *Gazi Üniversitesi Mühendislik-Mimarlık Fakültesi Dergisi* 2018/2018 (April 6, 2018). https://Doi.Org/10.17341/Gazimmfd.416513

Çetin, Cengiz. "Taş Koruma Ve Onarımında Temel Uygulamalar Ders Notları." 2023. Accessed June 22, 2023. https://Acikders.Ankara.Edu.Tr/Course/İnfo.Php?İd=4201

Dal, Murat. "Trakya Bölgesi Tarihi Yapılarında Kullanılan Karbonatlı Taşların Bozulma Nedenleri." *Vakıflar Dergisi* 34 (2010), 47–59. Http://Www.Midyat.Net

Dal, Murat - Yardımlı, Seyhan. "Taş Duvarlarda Yüzey Bozunmaları." *Kent Akademisi Kent Kültürü Ve Yönetimi Dergisi* 14/2 (June 15, 2021), 428–451. https://Doi.Org/10.35674/Kent.922313

Delgado Rodrigues, José. "Defining, Mapping And Assessing Deterioration Patterns İn Stone Conservation Projects." *Journal Of Cultural Heritage* 16/3 (May 1, 2015), 267–275. https://Doi.Org/10.1016/J.Culher.2014.06.007

Dereli, Mustafa Et Al. "Yapıların Cephe Kaplama Malzemelerinde Hasar Oluşturan Etkilerin Tespiti Ve Çözüm Önerileri - Konya Ptt Hizmet Binası Örneği." *Selcuk University Journal Of Engineering ,Science And Technology* 6/3 (September 1, 2018), 445–460. https://Doi.Org/10.15317/Scitech.2018.144

Dolar, Ayşe - Yılmaz, Ebru Şebnem. "Kültürel Yapılarda Biyolojik Bozunma Mekanizmaları." *Elektronik Mikrobiyoloji Dergisi* 12/1 (2014), 1–19.

Döndüren, M. Sami Et Al. "Tarihi Yapılarda Görülen Hasar Türleri." *Selçuk Üniversitesi Sosyal Ve Teknik Araştırmalar Dergisi* 13 (2017), 45–58.

Erdem, Hüseyin Onur - Caner, Evin. "Koruma Onarım Çalışmaları Öncesi Bozulmaların Teşhisine Bir Örnek: Hierapolis Kuzey Nekropolü 175 Nolu Anıtsal Mezar." *ART-SANAT Dergisi*, 73–89. https://Dergipark.Org.Tr/Tr/Pub/İuarts/İssue/47866/603980

Ersen, Ahmet. "Taş Korumada Son 20 Yıldaki Ve Yenilikler." *Restorasyon Ve Konservasyon Çalışmaları Dergisi* 10/10 (2013), 3–19.

Fitzner, Bernd. "Documentation And Evaluation Of Stone Damage On Monuments." *10th Internatıonal Congress On Deterıoratıon And Conservatıon Of Stone*, 677–690.

Görcelioğlu, Ertuğrul. "Yapı Malzemesi Olarak Kullanılan Başlıca Doğal Taş Çeşitlerinin Bazı Teknik Özellikleri." *İstanbul Üniversitesi Orman Fakültesi Dergisi* 16/1 (1976), 148–166.

Hasbay, Uğur Et Al. "Doğal Taşlarda Görülen Fizikomekanik Hasarlar". *Bilim Ve Gençlik Dergisi* 6/1 (2018), 2148–0273.

Hasbay, Uğur - Hattap, Sibel. "Doğal Taşlardaki Bozunma (Ayrışma) Türleri Ve Nedenleri". *Bilim Ve Gençlik Dergisi* 5/1 (2017), 23–45.

Hatir, Mehmet Ergün Et Al. "Deep Learning-Based Weathering Type Recognition İn Historical Stone Monuments". *Journal Of Cultural Heritage* 45 (September 1, 2020), 193–203. https://Doi.Org/10.1016/J.Culher.2020.04.008

Huang, Jizhong Et Al. "Study Of Internal Moisture Condensation For The Conservation Of Stone Cultural Heritage". *Journal Of Cultural Heritage* 56 (July 1, 2022), 1–9. https://Doi.Org/10.1016/J.Culher.2022.05.003

Kaltakçı, M. Yaşar – Temizci, Süleyman. "Konya Alaaddin Camii'nde Yapılan Zemin İyileştirme Ve Temel Güçlendirme Çalışmaları İle Alaaddin Tepesinin Sorunları", *İnşaat Mühendisliğinde Zemin Sempozyumu,* Konya: İnşaat Mühendisleri Odası İzmir Şubesi, 1991.

Kara, Hayriye Gülçin. *Tarihi Yığma Yapıların Taşıyıcı Sistemleri, Güvenliğinin İncelenmesi, Onarımı Ve Güçlendirilmesi*. İstanbul: İstanbul Teknik Üniversitesi Fen Bilimleri Enstitüsü, 2009.

Karataş, Lale - Alptekin, Aydın. "Kagir Yapılardaki Taş Malzeme Bozulmalarının Lidar Tarama Yöntemi Ile Belgelenmesi: Geleneksel Silvan Konağı Vaka Çalışması." *Türkiye Lidar Dergisi* 4/2 (December 30, 2022), 71–84. Https://Doi.Org/10.51946/Melid.1191769

Karkaş, Zeynep Sena. *Tarihi Yapıların Cephelerinde Kullanılan Kagir Yapı Malzemelerinde Konservasyon Çalışmalarının İrdelenmesi Ve Sistematik Bir Yöntem Önerisi*. İstanbul: İstanbul Teknik Üniversitesi Fen Bilimleri Enstitüsü, 2020.

Khooshroo, Sara Et Al. "İstanbul Süleymaniye Camii Taş Yüzeylerinde Tespit Edilen". https://Www.Researchgate.Net/Publication/325741941

Konyalı, İbrahim Hakkı. *Konya Tarihi.* 1. Cilt. Konya: Yeni Kitap Basımevi, 1964.

Konya Vakıflar Bölge Müdürlüğü Arşivi, 2023.

Konya Valiliği Çevre, Şehircilik Ve İklim Değişikliği İl Müdürlüğü. Access 23 August 2023. https://Konya.Csb.Gov.Tr/Buyuksehir-Belediyesi-Nden-Konya-Tarihine-İz-Birakacak-Ulusal-Yarisma-Haber-272345

Kılıç, İsmail. "Yapı Malzemesi Olarak Yenimuhacir Kumtaşının Fiziksel Ve Mekanik Özellikleri." *Gaziosmanpaşa Bilimsel Araştırma Dergisi (GBAD)* 6/3 (2017), 01–11. Http://Dergipark.Gov.Tr/Gbad

Konak, Ayşin Et Al. "Açık Hava Koşullarında Sergilenen Taş Eserlerde Bozulma - Bozunma Süreçleri Ve Koruma Yöntemleri." *Adıyaman Üniversitesi Sosyal Bilimler Enstitüsü Dergisi* 0/42 (December 29, 2022), 194–226. https://Doi.Org/10.14520/Adyusbd.1169901

Mahrebel, Hasan Ali. *Tarihi Yapılarda Taşıyıcı Sistem Özellikleri, Hasarlar, Onarım Ve Güçlendirme Teknikleri*. İstanbul: İstanbul Teknik Üniversitesi Fen Bilimleri Enstitüsü, 2006.

MEB. "T.C. Millî Eğitim Bakanlığı İnşaat Teknolojisi Taş Bozulmalarını Teşhis Etme." https://docplayer.biz.tr/18176378-T-c-milli-egitim-bakanligi-insaat-teknolojisi-tas-bozulmalarini-teshis-etme.html

Öcal, Ali D. - Dal, Murat. *Doğal Taşlardaki Bozunmalar*. İstanbul: Mimarlık Vakfı İktisadi İşletmesi, 2012.

Özata, Şerife. *Kapadokya Bölgesi Kaya Oyma Yapı Sorunları Ve Çözüm Önerileri*. İstanbul, 2015.

Pope, Gregory A Et Al. "Geomorphology's Role İn The Study Of Weathering Of Cultural Stone." *Geomorphology* 47/2 (2002), 211–225. https://Doi.Org/Https://Doi.Org/10.1016/S0169-555X(02)00098-3

Sevindi, Burak. *Konya Ve Çevresinde Yer Alan Vakıf Kayıtlarında Ulu Cami Olarak Geçen Camiler*. Konya: Konya Teknik Üniversitesi, Lisansüstü Eğitim Enstitüsü, Yüksek Lisans Tezi, 2020.

Şirikçi, Saadet Tuğba. *Tarihi Eserlerde Yapı Malzeme Cinslerinin Araştırılması Ve Korunmaları İçin Alınacak Önlemler*. İstanbul: Haliç Üniversitesi Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi, 2013.

Török, Á - Přikryl, R. "Current Methods And Future Trends İn Testing, Durability Analyses And Provenance Studies Of Natural Stones Used İn Historical Monuments." *Engineering Geology* 115/3–4 (October 2010), 139–142. Https://Doi.Org/10.1016/J.Enggeo.2010.07.003

Vural, Binnaz - Dal, Murat. "Mimari Yapılardaki Doğal Taş Malzeme Bozunmalarının Nedenleri Ve Türleri." *Mimarlık Bilimlerinde Güncel Konular-2022*, 261.