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Araştırma Makalesi

Material Destroyed According To Light Exposure Times In Architectural Exterior Coverings

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Abstract

Facades, which are the faces of buildings and cities, are the elements that affect the city and the user with their designs. However, facade coatings do not remain as new as the first day they were made. The first important parameter here is the type of quality material used. Because light interactions occur due to the internal structure of the materials used in the facade cladding. The resistance of materials to daylight differs in terms of illumination level and duration. In international standards, there is a categorization as insensitive, less sensitive, moderately sensitive, and very sensitive materials. This study analyzed discoloration and physical variation in daylight for some of these materials. Accordingly, dark wood, light wood, paint, etc. A simulation program was used to measure the damage caused by exposure to light on the facade cladding of some materials. The color fading effect of light is due to parameters such as the continuity of the light and the high level of daylight. In the selection of materials used for facade cladding, stone, metal, composite metals and UV-resistant paint types that are insensitive to light or less sensitive should be used.

Keywords: Daylight, facade lighting, artificial light, paint fading, architecture, physical environment

INTRODUCTION

Since the past, materials, colors, patterns, textures, symbols, or symbols unique to themselves have been used on the façade, voluntarily or involuntarily, in different environments, cities, and societies. In this way, its unique character, social and cultural characteristics are reflected in the city and the environment through the façade. Facades are the most important elements that reflect urban changes with factors such as construction techniques, technology, material and color diversity, as well as new uses, legal sanctions, and deterioration of building proportions. Building facades are the building parts that are seen from the outside and determine the taste. When buildings are first seen, they make their impact on people with the appearance of the facades and the materials used. The visual effects of buildings are primarily determined by the geometry of the facades, their appearance, and the quality of the materials used. Generally, in facade coatings; various types of metals, wood, precast, aluminum composite panel, natural stone, and PVC siding are used. Exterior cladding is preferred because of the advantages it provides in terms of sound and heat insulation as well as visuality. In this way, the facade cladding reduces the heat transfer from the outside and increases the transmission resistance of the heat. Thanks to the exterior cladding, cooling or heat loss is reduced if the heat in the building is cut off. In general, exterior cladding is used to protect the building from bad weather conditions (rain, hail, snow, sandstorm, sun rays, wind noise) and to integrate the architectural structure of the building with different color options and designs. In addition, its sound insulation feature, reduces the sound coming into the building. Facade cladding protects the building against water and wind and extends the life of the building. There are various types of materials used in architectural exterior cladding. Different materials react differently to environmental factors. the durability of the materials that make up the structure; The way they are used and the environmental conditions in their environment reveal the functionality of these materials. Materials used in exterior cladding designed for architectural purposes can be classified into two main categories as organic and inorganic origin materials. Materials consisting of a combination of these are called composites. Organic materials; It is used in the facade designs of new generation modern buildings, on the walls of the vertical median and parking areas beside the road. Organic objects are commonly found in facade coatings; wood, paper, textiles, animal products, rubber, bark, plant extracts (some inks, pigments, and dyes), and biological examples. Light causes general fading or structural damage to organic objects. Especially daylight and artificial light sources, which emit high levels of UV, cause rapid weakening of plant and animal origin materials. Light-induced photochemical degradation of organic objects is cumulative and not reversible. Inorganic Materials; form the part of the cultural heritage that is least susceptible to degradation, often included in modern façades or historic buildings. However, slow but unavoidable aging is also inevitable for inorganic materials. Inorganic objects share certain common vulnerabilities. These;

- Being exposed to excessive pressure or excessive heat,
- Changing their chemical structure by reacting with the environment, ie corrosion and dissolution of components,
- Porous structure (unglazed ceramic and stone),
- Collecting pollutants such as water, salt, dirt, acid on their surfaces,

it is in the form. The advantage of inorganic materials is that they are generally not sensitive to light, except for some types of glass and pigments. Inorganic objects are commonly used in facade coatings; metals, alloys, ceramics, stone, glass, and objects of mineral origin. Composite materials; consist of a combination of two or more different materials. They can contain both organic and inorganic materials and have properties of both. Because of these features, they react to the environment in different ways and rates. In some cases, the materials that make up the composite object may react against each other, creating physical stress and causing chemical interactions that lead to deterioration. Today, American siding, silicone, composite, stone, wood, glass, ceramic, precast, etc. can be used in exterior cladding. materials are often used. Examples of exterior cladding made of different materials are shown below. Figure 1 shows the precast application on the exterior. Figure 2 shows the stone application on the exterior. Figure 3 and Figure 4 show metal applications on the exterior.

Figure 1. Precast application on exterior

Figure 2. Stone application on the exterior

Figure 3. Exterior metal cladding application

Figure 4. Modern metal cladding application on the exterior

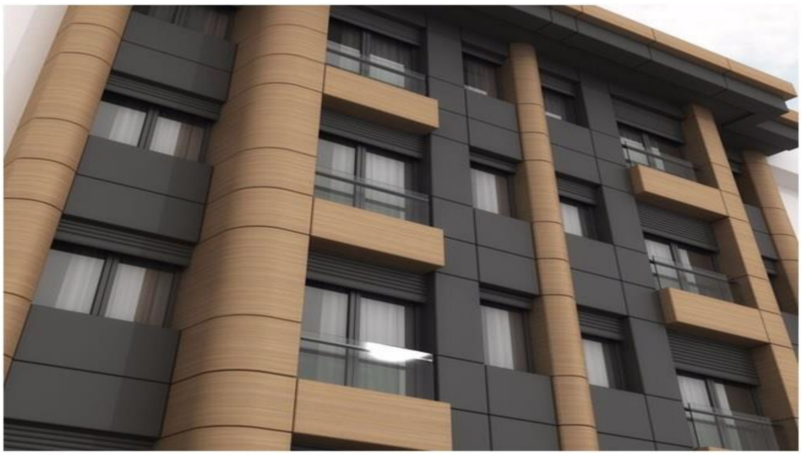

Figure 5. Composite application on exterior

Figure 6. Buildings with exterior composite application

Figure 7. Exterior glass application

Composite applications on the exterior are shown in Figure 5 and Figure 6. Figure 7 shows the glass application on the exterior.

Light Effects On Facade Materials

When the light spectrum to which facade coatings are exposed is examined, it consists of three parts: ultraviolet (UV) light, visible light, and infrared (IR) light. Figure 8 shows the spectrum form of the light.

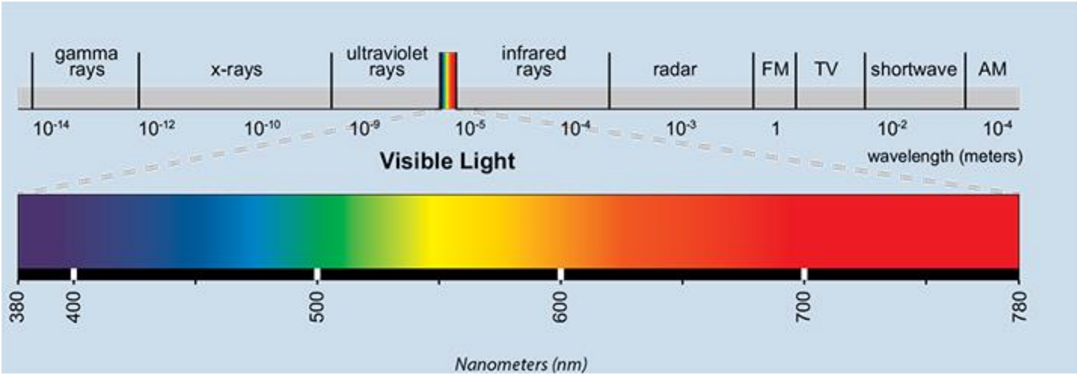

Figure 8. Spectra form of light

Light is a kind of electromagnetic radiation, light energy is reflected from or absorbed by the object on which it falls. This may support two different processes that can cause objects to deteriorate: radiant heating and photochemical phenomena (CIE 157, 2004). Radiant heating is the occurrence of a temperature rise on the surface of the material exposed to the light source. The surface expands relative to the body of the object and moisture moves away from the surface material. Its symptoms can be seen as surface cracking, removal of surface layers, and color spots (Rea, 2000). The first law of photochemistry called the Grotthus-Drapper Prin principle; predicts that in order for the photochemical event to occur, the light must first be absorbed by a part of the system. The second principle of photochemistry, called Stark-Einstein, states that a molecule can absorb only one quantum of radiation. The absorption energy in the resulting excited molecule can be dissipated by photophysical and photochemical processes (Hon, 1981). If the absorbed light energy breaks its molecular bonds or rearranges the atoms in an object, causing chemical changes on the surface, this is called photochemical event or photochemical degradation. Four factors determine the effect level of the photochemical event: the amount of light exposure, the exposure time, the spectral power distribution of the radiation, the action spectrum of the material receiving the radiation (CIE 157, 2004). The process in the photochemical event is quite different from radiant heating and the damage is usually more serious. Photochemical damage caused by natural lighting and artificial lighting in exterior cladding; causes deterioration of many materials or can increase the rate of deterioration. This damage appears as physical and structural changes such as weakening of materials, deterioration of synthetic and natural materials, oxidation of varnishes and certain pigments, the increased surface temperature of objects, bleaching, discoloration, yellowing, and darkening of paper, textiles, and woods (Pavlogeorgatos, 2003). Once photochemical degradation is initiated, photochemical reactions can continue even after light exposure or UV radiation has ceased. This means that objects continue to deteriorate even if they are kept in the dark (HCC, 1998a). The property of light has an important role in the damage process. Light has wavelengths of different frequencies, and when the wavelength gets shorter, the energy output increases (Corr, 1999). All light, especially light in the ultraviolet (UV) and infrared (IR) regions of the spectrum, damages materials, causing chemical changes. The most dangerous photochemical damage is caused by UV rays (below 400 nanometers). However, a common misconception about radiation is that eliminating ultraviolet radiation will eliminate problems. This approach is not correct, because it is the energy that triggers deterioration from the fading of colors to chemical reactions, and light is energy no matter which part of the spectrum it is in (Ajmat et al., 2011). The destructive capacity of visible radiation can cause fading or darkening of some pigments and dyes, although not as much as IR or UV radiation (Shelley, 1987). In summary, visible light contributes to both vision and damage; invisible infrared (IR) and ultraviolet (UV) energy only contribute to damage (Rea, 2000). The important point about the damages of radiation; even at low levels, the damage caused by light exposure is irreversible (Edson and Dean, 1996; NPS, 2016). The damage caused by light exposure to the facade cladding is proportional to the product of the intensity of the light and the exposure time to the light. However, it is important to know the effects of radiation on materials and to take the necessary precautions to prevent deterioration and delay aging.

Infrared light effect

Infrared radiation has less energy than UV radiation and visible light. However, it emits intense heat. This heat raises the ambient temperature and affects the relative humidity in a room, creating hot spots and accelerating chemical degradation (Corr, 1999). Heat also activates or energizes molecules in materials, making them more reactive, volatile, and vulnerable (Edson and Dean, 1996). In a changing thermal environment, materials undergo dimensional changes and deformations in response. Stress occurs when materials with different coefficients of thermal expansion come into contact, and especially when materials with high coefficients of expansion are present. Partial shading of the object can cause different heating effects (CIE 157, 2004). If the illumination is positioned or focused too close to an object, infrared light can increase the object's temperature, which can lower the water content of porous materials and cause them to become brittle. In addition, infrared radiations can cause mechanical stresses due to the effect of heat, causing expansion of materials and faster progression of chemical changes. Consequently, infrared radiation can amplify the destructive effects of both visible light and ultraviolet radiation (HCC, 1998a; Shelley, 1987). Lighting sources that cause heat accumulation; sunlight, incandescent lamps, quartz halogen lamps, fluorescent ballasts (NPS, 2016). Among these sources, the most prominent sources of infrared radiation in facade cladding are; High-intensity incandescent lamps above 5000 lux and direct sunlight. Sunlight or intense incandescent lighting can raise ambient surfaces to temperatures of 40°C or higher. This increases the thermal degradation rate by a factor of 20 or more (Michalski, 2018).

Visible light effect

The principle that light exposure on the object is a product of illuminance level and time is called the "Law of Equivalence", "Bunsen-Roscoe Law" or "Principle of Equivalence". According to the equivalence principle; Provided that their spectral distribution is the same, low light levels for long periods cause the same damage as short-term high light levels (CIE 157, 2004). For example, illuminating an object with 50 lux for 8 hours has the same effect as lighting it at 100 lux for 4 hours. Visible light is often accompanied by ultraviolet radiation, which can cause damage faster than visible light, and infrared radiation, which heats the material (HCC, 1998c). The damage function for an object is the spectral distribution of radiation that causes a harmful change in the material of the object. UV radiation contributes significantly to this phenomenon. Therefore, the damaging effect of light is often assumed to be reduced in visible light, but this is not always the rule. Because, depending on the material structure, especially visible high-energy light (400–500 nm) can cause significant damage (Eng, et al., 2016). Visible radiation fades or bleaches colors. For example, it causes fading of volatile dyes, bleaching of wool and paper, and color changes in some organic pigments (Michalski, 2018; Shelley, 1987).

Ultraviolet light effect

Ultraviolet radiation is radiation with shorter wavelengths and higher energy compared to visible and infrared radiation. In the electromagnetic spectrum, UV radiation lies between the blue end of the visible spectrum (400 nm) and low-energy X-rays (100 nm). UV radiation is traditionally classified into 3 bands, in order of increasing energy: UVA (320-400 nm), UV-B (280-320 nm), and UV-C (100-280 nm) (Zayat et al., 2007). UV radiation is a potent cause of photochemical damage. So much so that even a small amount of light, including UV, can cause irreversible, cumulative damage. Because UV radiation is extremely energetic, it tends to affect the stability of the materials that make up an object. UV-induced damage; discoloration, including yellowing and fading (such as yellowing of the varnish and some plastics, and fading of many inks, paints, and pigments), is seen as weakening and brittleness (CCI-2/1, 2015; NPS, 2016). Chemical changes initiated by UV radiation seriously affect the aesthetic quality of many products by damaging fibers and polymers (Boye et al., 2010) (HCC, 1998c. Yellowing of silk, oxidation of lacquered surfaces, darkening of light woods, fading of dark woods, natural and synthetic Color changes in resins, degradation of cellulose and proteinaceous materials are examples of the harmful effects of UV rays on materials (Shelley, 1987) The sun is the main source of ultraviolet radiation Infrared light (55%) and visible light (40%) make up most of the radiation from the sun, at ground level about 5% of solar radiation is ultraviolet radiation mostly in the UV-A range (Zayat et al., 2007). In addition to UV radiation from the sun, there are various artificial light sources that emit UV radiation. The most common artificial sources of UV radiation are; arc lamps and fluorescent lighting. Arc lamps emit light in a wide range of wavelengths, including large amounts of UV-A and UV-B and some UV-C light. Fluorescent lamps produce UV radiation by ionizing low-pressure mercury vapors (Zayat et al., 2007). The amount of UV produced by different light sources is usually expressed in microwatts per lumen, µW/lm. According to CIE157-2004 criteria UV content 400–1500 µW/lm for Daylight, UV content 70–80 µW/lm for Tungsten halogen lamps, UV content 40–170 µW/lm for fluorescent lamps, UV content 30–100 for metal halogen lamps UV content of µW/lm and for LED lamps is 5 µW/lm.

MATERIALS and METHOD IN FACADE COATING

When the materials exposed to light in facade coatings are examined in terms of their Light Sensitivity and Deterioration in the Coating, the building materials grouped as Insensitive Materials are Inorganic materials. This group includes metals, stone, ceramics, glass, precast and composite metals. Building materials in this group are not affected by light as they are insensitive to light. In the category of insensitive materials, the marble (stone) application on the exterior is seen in Figure 9. One of the insensitive materials, Figure 10 shows the application of modern artistic metal cladding on the exterior, Figure 11 shows an application where silicone and glass are used together on the exterior, and Figure 12 shows examples of facade applications where composite-silicone and glass are used together on the exterior.

Figure 9. Marble application on the exterior

Figure 10. Modern artistic metal cladding application on the exterior

Figure 11. An application where silicone and glass are used together on the exterior

Figure 12. Facade application where composite-silicone and glass are used together on the exterior

Building materials grouped as Low Sensitivity Materials are UV light resistant paints for external environmental conditions, modern PVC, siding, and rubber. Cracking and chalking effects are seen in these materials. Figure 13 shows the PVC-Siding application on the exterior.

Figure 13. PVC-Siding application on exterior

Building materials grouped as Medium Sensitive Materials are wood, non-UV resistant paints, traditional plastic, and rubber. Graying and corrosion of wood in long-term light exposure; conventional plastic, cracking in rubber; Chalking effects are seen in paints that are not UV resistant. Figure 14 shows the wood application on the exterior.

Figure14. Exterior wood application

Oil paint and pale wood are included in the building materials grouped as High Sensitivity Materials. Chalking in oil paints containing photosensitive pigments under prolonged light exposure; yellowing effects are seen on pale wood. In Figure 15, a pale-colored wood application is seen on the exterior.

Figure 15. Pale colored wood application on the exterior

Materials that can be used widely or rarely in facade cladding can be classified as organic, inorganic and composite materials. Depending on the brightness level of the light and the exposure times on these materials, light-induced aging effects are seen on the surfaces of the facade claddings. These effects can increase or decrease depending on the material type. In addition to classifying facade cladding materials as organic, inorganic, or composite, it is also necessary to classify them according to their sensitivity to light. Various institutions active in the field of conservation have divided the materials into categories, generally between 3 and 5, according to their light sensitivity. For example, the North American Society of Lighting Engineers (IESNA) materials according to their sensitivity to light; grouped as high sensitive, moderately sensitive, and low sensitive (Rea, 2000). Australian Institute of Cultural Materials (AICCM) materials; classified as highly sensitive, moderately sensitive, and insensitive (HCC, 1998c). This difference between institutions is related to the variety of materials they have or consider. Materials vary greatly in their sensitivity to light exposure. The color change is the clearest indicator of light-induced damage to exterior cladding. Some researchers have used ISO grades based on the Blue Wool Standards to classify the sensitivities of pigments. The susceptibility classifications of pigments put forward by the International Commission on Illumination (CIE) are based on ISO ratings in the Blue Wool Standards. While defining the relationship between light sensitivity and ISO degrees (CIE 157, 2004), materials with Sensitivity Category 1, that is, "Insensitive" to light, are not numbered according to their ISO degrees. Materials with Sensitivity Category 2, i.e. "Low Sensitivity" to light, are numbered 7 and 8 according to the ISO rating. Materials with Sensitivity Category 3, that is, "Moderate Sensitive" to light, are numbered 4, 5, and 6 according to the ISO rating. Materials with Sensitivity Category

2, i.e. "High Sensitivity" to light, are numbered 1, 2, and 3 according to the ISO rating.

The Effect of Light on Wooden Facade Cladding

Wooden materials used in facade cladding may consist of wood alone or composite materials that are a combination of other materials and wood. It is one of the oldest materials used by humans because it is easier to find and relatively easy to produce than other materials. The chemical composition of wood is approximately 50% carbon, 44% oxygen, 6% hydrogen; May contain small amounts of other chemical elements and pigments. The main elements come together to form mainly cellulose, hemicellulose, and lignin in different proportions depending on the tree species (Fabbri, 2012). The wood in a living tree consists of cells made of cellulose that pass nutrients and waste products through the wood. As the tree grows, new layers of cells are added to its outer periphery. At the end of growth, old cells in the interior of the tree produce lignin in their cell walls and die. The outer part of the wood is called sapwood. The middle part of the tree trunk surrounded by sapwood is called heartwood. Differences between cell types in wood and their relationships with each other; determine the distinguishing features of tree species such as color, grain, and durability. Many trees also contain other chemicals such as resins and oils that affect the nature and appearance of their wood (HCC, 1998b). Sensitivity to climatic conditions in woods is strongly related to the amount of cellulose, hemicellulose, and lignin in its composition, and lignin is most susceptible to photochemical degradation. Light bleaches colors by breaking down the lignin component in wood. Therefore, the cellular structure of wood deteriorates. This light-induced damage on wood; seen as fading and color changes (HCC, 1998b). Ultraviolet rays, the most harmful component of light, are the main factor responsible for the deterioration of wood, as it initiates a series of chemical reactions on the wood surface. Exposure to UV rays results in surface roughness and alteration, breaks, and cracking (Zayat et al., 2007). Light changes the natural color of the heartwood, causing light woods to be darker and dark woods lighter, fading any paint on the wood and making the finish brittle. Figure 16 shows before and after UV light exposure for Wood.

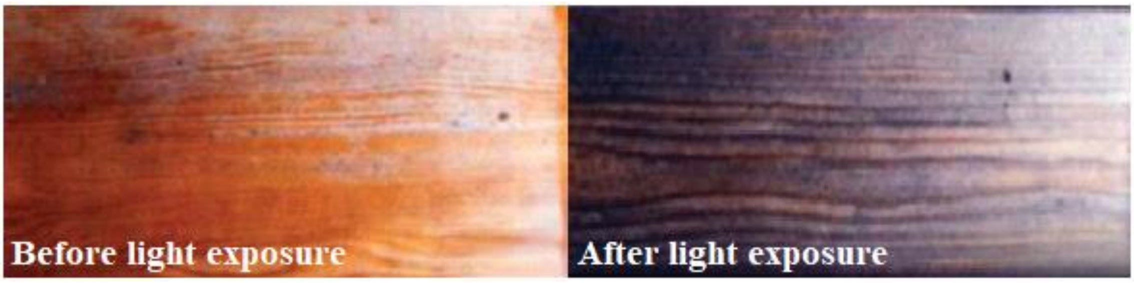

Figure 16. Wood before and after UV light exposure (Zayat et al., 2007)

Painted wood surfaces can be highly resistant to light because the paint penetrates the wood and creates a strong bond. However, because the paint forms a film on wood, the wood's expansion and contraction in response to changes in environmental conditions cause the paint to have a tendency to crack and loosen. Deterioration of paint binders on the wood surface is caused by the light (both visible light and ultraviolet radiation), which can cause powdering and color changes. Light causes deterioration, cracking, and loosening of natural resin coatings as well as paints on wood. For wooden objects, not only radiation is harmful, but also the heat produced by the sun causes damage.

Effect of Light on Facade Cladding for Metal-Based Materials

Metals throughout human history; have been used in the production of many objects, such as weapons and tools, functional objects, and decorative purposes, in their pure form or combined with other metals. Therefore, metal objects are frequently used in facade cladding. Despite their apparent strength, metals can be vulnerable to physical damage and chemical degradation (corrosion) (HCC, 1998b). The main causes of deterioration of metal objects in facade lighting; relative humidity, extreme temperatures, atmospheric pollutants, lack of maintenance (NPS, 2002). The heat increase on material surfaces caused by infrared radiation can cause relative humidity changes and temperature increases in metal objects. Although metals are included in the category of non-photosensitive objects in classifications based on material sensitivities, there are several restrictions that should not be ignored. This; is the process of protecting the metal and protecting the metal. If there is any coating on a metal surface, UV rays can adversely affect the coating. Photodegradation of anti-corrosion additives causes the loss of their protective properties (Serdechnova et al., 2014). For example, the coating material is applied to the silver mine after cleaning to prevent tarnishing, but coatings begin to deteriorate over time due to light and moisture and require constant maintenance (Rimmer et al., 2013). Also, lighting fixtures such as fluorescent light ballasts or ozone generating transformers can cause damage to metal objects. Because ozone causes corrosion on metal surfaces (NPS, 2002).

Effect of Light on Paint in Facade Cladding

On the façade, color is one of the main elements in the design's gaining meaning and identity. Color has been on the facade throughout history; It has been used for many different purposes such as climatic conditions, history, culture, religion, symbol, and perception. Correct use of color is associated with establishing color harmony. Color, light, shadow, and the material used to create harmony. There are also factors that affect the spatial usage differences of color. Color is usually based on aesthetic, functional, and personal preferences in the interior. Color in the exterior and especially on the facade; In addition to aesthetic, functional, and personal factors, it can be based on the natural and built environment and local characteristics of the environment such as climatic characteristics, culture, and identity. (Zengel & Kaya, 2007; Cidem and Tekin, 2020). Color is used in architecture to emphasize the characteristic features, form, and material of the building and to make it more prominent. When used correctly, color is effective in expressing the character of a building and the emotions it is desired to evoke in the perceiver. In the past, color was used only to protect building materials, to highlight structural elements and textural features, to emphasize the architectural composition or the relationship between a series of spaces. gained importance after its use. Especially since the 20th century, the use of color on the façade has become an effective element in both the building and the city scale (Rasmussen, 1964; Cidem and Tekin, 2020; Şenyiğit, 2010; Tekin, 2018). Objects in most of the façade coverings contain coloring materials (paint) to increase the visual effect for decorative, ornamental, or artistic purposes. Light damages the colors of some objects. It causes fading and in some cases chemical changes of pigments, some dyes, and colorants. For example, organic pigments such as Gomagota are very susceptible to fading. Soil pigments are not affected by light, but vermilion turns black when exposed to light (Bradley, 2005). Organic (animal or vegetable origin) pigments tend to be more sensitive than others. The photochemical effect in the pigments can be noticed with drastic changes in appearance, especially in the watercolor medium. For example, Hooker's Green is a pigment mixture commonly used in landscape watercolors. It is obtained from highly durable Prussian blue mixed with Gomagota, a yellow pigment. Gomagota is susceptible to photochemical degradation and fades, leaving a greenish-blue color. Many of these delicate pigments have also been used in oil paints. However, the effects are less pronounced in oil paints, as the pigment layer is usually thicker and the oil medium provides greater protection (HCC, 1998c). Exposure to light also causes changes in the color of the paints, or eventually, the colors fade to the point of disappearance (Landi, 1998). In the low sensitivity category; There are materials rated 7, 8 (and higher) according to ISO Blue Wool Standards, paint palettes classified as stable, many high-quality modern pigments developed for outdoor use, and Vermilion. In the medium sensitivity category; Materials rated 4, 5, and 6 according to ISO Blue Wool Standards, most of the colors of fur and feathers, many color photographs are included. In the high sensitive category; Materials rated 1, 2, and 3 according to ISO Blue Wool Standards, most contain plant extracts. There are bright dyes and many cheap synthetic colorants on advertising signs, most early synthetic colors such as aniline, most felt-tip pen colors including black, most red and blue ballpoint inks, and most of the dyes used to color paper.

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