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An Experimental Study on Aderance Loss Through the Weathering of Synthetic Binder Based Ready-Made Plasters

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Abstract

In this study, the behavior of the ready-made plasters with synthetic binders, which are used as the last layer on the facades of the structures, against the effects of U.V. radiation, temperature and water, which are thought to be closely related to each other, was examined. Experimental work was carried out on the samples prepared for this purpose, and a special test cabinet was produced for the purpose of testing the samples for accelerated atmospheric conditions. In the experiment, U.V. radiation, heat and water effects were applied alone on one part of the samples and together on another part of the samples. As a result of the experiment, it was determined that the main factor causing aderance loss of ready-made plasters was water, and the water effect became more destructive with the effects of U.V. radiation and temperature change.

Keywords: *Ready-made plaster, aderance, U.V. radiation, heat, water.*

Sentetik Bağlayıcılı Hazır Sıvaların Aderans Kaybı Üzerine Bir Deneysel Çalışma

Öz

Bu çalışmada yapıların cephelerinde son kat olarak kullanılan sentetik bağlayıcılı hazır sıvaların, birbiri ile yakından ilişkili olduğu düşünülen U.V. radyasyon, sıcaklık ve su etkileri karşısındaki davranışları incelenmiştir. Bu amaçla hazırlanan numuneler üzerinde deneysel çalışma yapılmış, numunelerin hızlandırılmış atmosfer koşulları deneyine tabi tutulması için amaca yönelik özel bir deney kabini üretilmiştir. Deneyde, U.V. radyasyon, ısı ve su etkileri, bir kısım numuneler üzerinde tek başına, diğer bir kısım numuneler üzerinde birlikte uygulanmıştır. Deney sonucunda hazır sıva aderans zayıflamasına yol açan ana etkenin su olduğu, su etkisinin, U.V. radyasyon ve sıcaklık değişimi etkisiyle birlikte daha çok tahrip edici hale geldiği tespit edilmiştir.

Anahtar kelimeler: *Hazır sıva, aderans, U.V. radyasyon, ısı, su.*

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1. Introduction

The external walls of buildings generally consist of insulation layers, interior and exterior coating, in addition to the core. Exterior coatings are mainly applied to protect the building shell from the negative effects of external conditions. Building materials are exposed to many destructive environmental effects (Sarıkaya & Arpacıoğlu, 2019). Physical environment and climatic factors provide important data for architectural design elements (Arpacıoğlu & Ersoy, 2013). Coating materials applied in the form of panels cover a wide area from wood to natural stone, ceramic to glass, foam to metal, composite to polycarbonate, and the properties of each vary according to the type of material. In addition to these, there are also liquid coating materials that can be applied to the interior and exterior surfaces of the wall, which are ready-mixed or prepared on the construction site. Liquid coatings are applied in different types and thicknesses depending on the surface to be coated (Marriage & Allaf, 2021).

Traditional plasters have been the most widely used liquid coating materials since the past. They are generally used as the first layer to cover surface irregularities and prepare them for other layers. Traditional plasters, which are produced using inorganic binders such as lime, gypsum, and cement, with thicknesses ranging from 1 to 3 cm, are generally called mineral-bound plasters. There are also types of mineral-bound plasters that are reinforced with synthetic resins (Diri, 2003).

Apart from these, plasters colored with various pigment materials are also produced using synthetic resin-based organic binders. These types of plasters do not require a paint or coating layer and are used as the outermost layer in the formation of the building shell (Diri, 2003).

1.1. Aims and Scope

The external durability of building materials, especially external coatings, which are constantly exposed to the external environment and atmospheric effects during the usage process of buildings, has always been a concern for architects, builders and users. One of the coating types commonly used on the facades of buildings is synthetic-based coatings. Therefore, the degradation mechanisms of synthetic-based external facade coatings under weather conditions have been the subject of various studies since the past. For this purpose, in addition to long-term experiments carried out in the natural environment, various accelerated wear tests are also carried out in the laboratory environment (Yang et al.,2002).

The aim of this study is to examine the factors that cause the degradation of synthetic-based coatings under external weather conditions, and to help make predictions about the service life of coatings according to climate types. For this purpose, synthetic-based ready-made plasters, which are one of the synthetic-based coating materials and used as the finishing layer on the facades of buildings, were examined in this study and their behavior against physical environmental effects was examined with 3 parameters (temperature, water and U.V. effect) that are thought to be closely related to each other. Based on the findings obtained, evaluations were made about the combinations in which these parameters are more effective and their shares in degradation, and recommendations were made to extend the service life of ready-made plasters.

1.2. Ready-Made Plaster

The term ready-made plaster is used for plasters that are available in the market in ready-mixed form. One advantage of ready-made plasters is ease of application. Those in powder form can be applied by adding water, while those in liquid form can be applied directly. Since ready-made plasters contain polymers that help retain moisture, they have a shorter curing time than traditional plasters (Gonçalves da Silva, 2004).

The thickness of the ready-made plasters varies from 1 to 4 mm depending on the application surface and method. A smooth application surface is needed as this thickness is often insufficient to cover surface defects. This is why the application is usually done after applying a mineral based plaster on the outer wall. In addition, there are ready-made plaster applications on paper surfaces made with gross concrete or concrete, aerated concrete or other blocks, or on heat-insulating layers such as synthetic foam, glass wool placed outside the wall (Diri, 2003).

Ready-made plasters with a unique texture and decorative feature are applied to the wall by a trowel, roll or spray method. Synthetic-based ready-made plasters receive sockets faster than mineral-based plasters and are more elastic. At the same time, according to the internal structure of the synthetic-based plasters, the water impermeability and vapor diffusion resistance factors are more. As with other coating materials, the first of the two functions that are mainly expected from ready-made plasters is to protect the substrate against external influences. The healthy use time of protective coatings varies according to the application and material quality and according to the external environment conditions. The second function is the beautification of surfaces that do not look very aesthetically pleasing in their uncoated form (Diri, 2003).

1.3. Effects Causing Loss of Adhesion in Ready-Made Plasters

The loss of the protective effect of ready-made plasters generally occurs in two phases. The first is the decomposition of material with atmospheric effects. This is called degradation. The main atmospheric effects affecting coating materials include temperature changes and precipitation. The main source of these effects and all other climatic events is solar radiation. U.V. radiation at wavelengths below 400 nm is high energy and destroys the structure of organic materials (Çiftçi & Arpacıoğlu, 2021).

The first signs on a macro-scale of the degradation caused mainly by U.V. radiation, water and oxygen, and pollutants in the atmosphere; in turn, loss of gloss is the loss of surface dusting, thinning of the dry film layer, hardening, brittiness and the beginning of the formation of capillaries (Philip & Schweitzer, 1999).

The second phase is the loss of the adhesive power of the ready-made plaster and the elimination of the protective function on the substrate. This is evident when the capillaries turn into larger cracks and the flake spills begin (Philip & Schweitzer, 1999).

The combination of the chemical effects from the substrate with the effects in the atmosphere in the loss of aderance, other physical environmental effects such as solar radiation, repetition of heating cooling, and most importantly, the water effect appear to play a role (Silva & Silva, 2007).

The electro-chemical reactions that cause ions to form and the reactions that are basically initiated by water cause the aderance of the coating to weaken with the substrate as a result of such reactions, corrosion or erosion products are formed between the substrate and the coating material. Exterior cladding can face the effect of water in two forms. The first of these is direct contact with water with effects such as rain, rain and snow. The second is the effect of water vapor in the air. As a result of these effects, almost all external surfaces can be said to be damp or wet at certain times of the day depending on the humidity and air temperature, this film layer covering the surfaces is more or less pure and distilled, contaminated with acid pollutants, oxygen and dust. As a result, even in areas of the surface that never have direct contact with flowing water, we can talk about an effect equal to immersion at a certain rate. In both cases, water molecules enter the coating. These two features are among the most prominent parameters that affect the aderance of the coating to the substrate. The mechanism of the effect of water on the coating is formed in the following order (Schmid, 1998);

- Absorption of water molecules into the film layer,
- Water entering the interface between the film layer and the substrate,

The formation,

- Corrosion and erosion formation in the substrate,
- Flaking or peeling of the film layer (Schmid, 1998).

In addition, the condensation that can occur within the outer wall section, depending on the characteristics of the layers that make up the outer veil, the order of arrangement and the physical conditions of the environment, is another important factor. Condensation usually occurs on the surface between the ready-made plaster and the substrate if the vapor permeability of the inner plaster and other layers is greater than the vapor permeability of the most outermost ready-made plaster, and the outer wall is left cold without thermal insulation applied to the outer surface, which can cause serious damage. In addition, thermal stresses resulting from rapid temperature changes, or stresses resulting from different expansion or contraction tendencies, especially when the outer layer and the thermal expansion coefficient of the substrate are not close to each other, and the fatigue effect and other mechanical effects resulting from their continuous occurrence, can also cause aderance loss. It is also known that effects such as freezing dissolution repeats, salt crystallization pressure and osmotic pressure effect, vapor pressure in the structure from the internal environment to the outside, U.V, degradation caused by radiation, chemical and microbiological corrosion lead to attenuation (Ribeiro et al.,2009).

2. Material and Method

In order to monitor the performance of polymer materials against external effects, long-term exposure tests are carried out in different climate zones and different terrains, as well as accelerated tests are carried out under laboratory conditions. In accelerated wear tests, elements such as UV radiation, water, heat, and salt fog, depending on the type of test, are used and these effects are given continuously or intermittently according to the determined program. Again, they are given alternately or superimposed according to the determined program. Physical and chemical deteriorations occurring in the material as a result of determined cycles are observed and analyzed. ASTM G154, G53-88, D4329, D4587, ISO4892 are among the relevant standards. It is difficult to establish a direct relationship between accelerated wear time and real outdoor exposure time. However, when accelerated wear tests are carried out under controlled conditions, they can be compared with long-term real outdoor exposure tests. Outdoor conditions are simulated in accelerated wear tests (Yang et al., 2002).

In this study, a series of experiments were carried out to examine the behavior of ready-made plasters in the face of U.V. radiation, temperature and water effects, and the samples prepared for this purpose were subjected to accelerated atmospheric conditions.

In the experiment, 30 x 60 cm size asbestos cement sheets with a thickness of 1.5 cm were used as a base. On the underlays, polymer-based wire mesh with 16 sieve No. was laid in accordance with TS 7847, and then ready-made plaster with 3 mm thick gray acrylic copolymer emulsion binder was applied to it prepared for outdoor conditions. Then the plates were allowed to dry for 28 days at room temperature, 55 ± 3% relative humidity in accordance with TS 7847. After finishing the drying, the ready-made plaster is divided into strips. The slicing process was done using a thin spiral parallel to the long edge, with one strip on each side being 3 cm and the remaining 12 medium strips being 2 cm.

In the accelerated air conditioning experiments, the plates were divided into 7 groups where different effects would be applied, and 3 plates were used for each group. Groups and codes are given in Table 1.

Table 1. Sample groups and codes

Group	Impact type	Code numbers
1	The U.V. radiation	UV 1-2-3
2	Warm up - cool down	Heat 1-2-3
3	Dry	Water 1-2-3
4	U.V. radiation + warm-up - cool-down	UV + Heat 1-2-3
5	U.V. radiation + drying	UV + Water 1-2-3
6	Warm-up - cool-down + Dry	Heat + Water 1-2-3
7	U.V. radiation + warm-up - cool-down + Dry	UV + Heat + Water 1-2-3

Aderance measurement tests on ready-made plaster with acrylic binder were performed on samples exposed to accelerated atmospheric conditions and on samples not exposed to any effect. The section diagram of the air conditioning device used in the experiment is given in Figure 1.

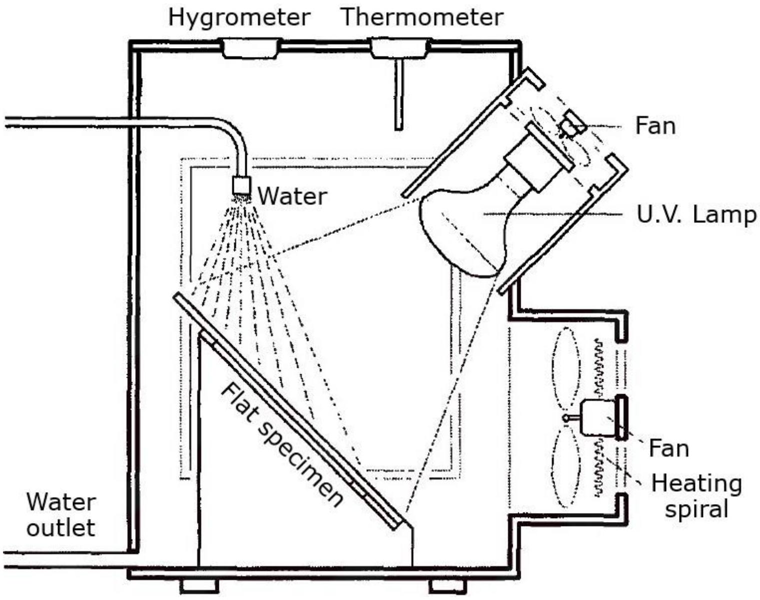

Figure 1. Section diagram of air conditioning cabinet (Created by the author)

The test cabinet features a U.V. lamp, a vertical mounted resistor fan, a water spray system and a water drain pipe. Inside the cabin, the plates stand at an angle of 45°, and the U.V. lamp is positioned at 45° with a perpendicular angle to the surface of the plate from a distance of 30 cm. The temperature inside the cab is controlled by the resistor fan. The heat emitted from the U.V. lamp is expelled by a second fan located behind the lamp. The test environment temperature and relative humidity are measured with a thermometer and a hygrometer placed on the top cover. The temperature of the surface of the plate is measured with a laser thermometer. There are also automatic thermostats in the cab to control the warm-up to cool-down times.

In warm-up – cool-down cycles, the warm-up – cool-down period is set to 1 hours with rev-adjusted fans and thermostats and the temperature is fluctuated between 15°C and 65°C.

In wet-dry cycles, after 15 minutes of soaking with the spray irrigation system to cover the entire plate surface with water, the fans are activated for drying and 5 hours and 45 minutes. expected. The period is set at 6 hours. According to this, 4 times in 24 hours, Turkey has been wetted according to the average annual rainfall amount.

The experimental study consists of two phases, accelerated air conditioning and aderance measurements.

Among the atmospheric effects, 3 parameters that are thought to be closely linked to each other, the U.V. radiation, temperature and water effect, were applied to experimental samples in the accelerated air conditioning cabinet. In the experiment, the effects of these parameters together with the effects they make on their own were examined.

UVA and UVB radiation measurements were made on the U.V. lamp used in the experiment to find the equivalent duration of action of the U.V. lamp, and the results were compared with light sky radiation. According to the results, it was accepted that the effect of the U.V. lamp on the surface of the plate for 15 days at a distance of 30 cm corresponds to the total radiation given by the sun in J/m^2 in a year.

The ready-made plaster strips on the plates put into the experiment were peeled in 4 stages and their aderance was measured.

In the first stage, aderances were measured by stripping 3 strips from each of the 21 slabs before exposing them to any effect.

In the second stage, after the samples were subjected to accelerated atmospheric effects according to the code numbers for 15 days in the experimental cabinet, 3 more strips of 2 cm were stripped. This 15-day period is considered to be 1 years under natural atmospheric conditions. During this period, 360 hours of U.V. radiation, 60 wetting-drying repeats, 360 heat-cooling repeats were applied.

In the third and fourth stages, the samples were subjected to accelerated atmospheric effects for 15 days and plaster strips were stripped. Thus, 3 stripes were stripped at each stage over each plate. The 3 cm strip at both ends has not been peeled to prevent the edge effects from being reflected on the results. (*This method was applied because there were some differences between the edge strips and the measurements made in the middle strips in the preliminary experiments.*) The last 3 strips on the longest plates in the test booth were subjected, according to code number, to 1080 hours of U.V. radiation, 180 wetting-drying repeats and 1080 heat-cooling repeats, or to the double or triple effects of these parameters for 45 days.

The method of strip stripping was applied during the aderance measurement phase. The coating layer applied in this method is separated by two lines parallel to each other. Thus, a certain width of a strip appears. Then a force is applied at a certain angle in this series, stripping the strip, and the force applied at this time is measured.

In this experimental study, a pulley in the form of a rectangular prism was prepared for the aderance measurement process on the ready-made plaster strips, which are experimental samples, and the plates were placed on the pulley with the plaster layer at the bottom. One end of the strip to be stripped is separated by 3 cm from the substrate and attached to the end of the strip with a weighted plastic container clamp. This contrivance can be seen schematically in Figure 2. Then, lead beads were added one by one into the container and the weight of the container started to be gradually increased. During peeling, the length of the strip through which the minimum force and force separating the plaster from the underlay were recorded. The most recent 3 cm portion was not taken into account to prevent the side effects from being reflected in the results.

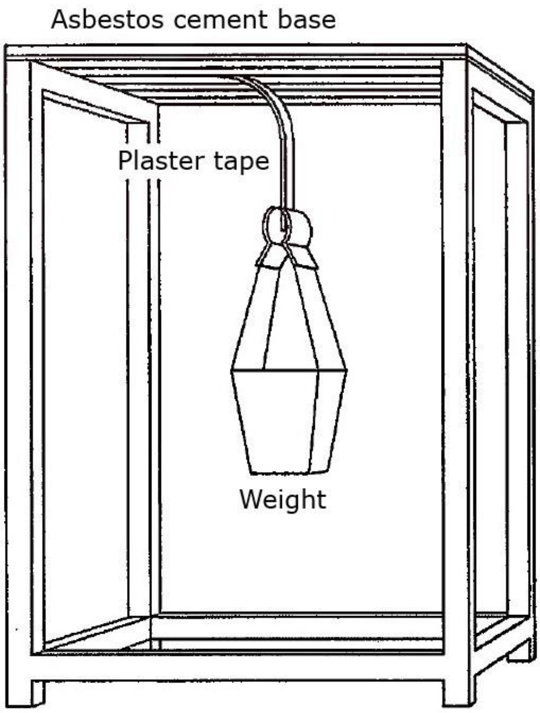

Figure 2. The contrivance used for measuring the aderance (Created by the author)

3. Findings and Discussion

In the experiment, 21 plates, including 7 group plates, were entered in gups of 3, 3 strips were stripped from the plates at each stage and weighted strip averages were calculated. According to the average, in the samples where the U.V. radiation, warm-up-cool and wetting-drying cycles act alone, the water effect is seen to weaken the aderance. Samples exposed to U.V. radiation showed no significant aderance loss. On the contrary, it was observed that the strips stiffened according to the samples that were not exposed to any effect and slight increases in aderance occurred in these samples.

Tables from Table 2 to Table 8 are related to the experimental results. Tables 2, 3, and 4 give the results obtained when the parameters are applied alone, and Tables 5, 6, 7, and 8 give the results obtained when the parameters are applied together.

Table 2. Results of single effects (U.V. radiation)

Code No	Average breakout force [gr]			
	Zero	15 days	30 days	45 days
UV-1	2497	2500	2510	2488
UV-2	2509	2521	2513	2502
UV-3	2506	2511	2510	2499
Overall average	2504	2511	2511	2496
Rate of change of breakout force	1	1.003	1.003	0.997

Table 3. Results of single effects (Heat)

Code No	Average breakout force [gr]			
	Zero	15 days	30 days	45 days
Heat-1	2492	2464	2429	2376
Heat-2	2510	2505	2459	2390
Heat-3	2503	2501	2479	2388
Overall average	2502	2490	2456	2384
Rate of change of breakout force	1	0.995	0.982	0.953

Table 4. Results of single effects (Water)

Code No	Average breakout force [gr]			
	Zero	15 days	30 days	45 days
Water-1	2502	2246	1992	1854
Water-2	2507	2284	2037	1816
Water-3	2499	2237	1997	1811
Overall average	2503	2256	2008	1827
Rate of change of breakout force	1	0.901	0.803	0.730

Table 5. Results of multiple effects (UV + Heat)

Code No	Average breakout force [gr]			
	Zero	15 days	30 days	45 days
UV + Heat-1	2496	2495	2431	2295
UV + Heat-2	2494	2472	2449	2310
UV + Heat-3	2505	2477	2453	2316
Overall average	2499	2481	2444	2307
Rate of change of breakout force	1	0.993	0.978	0.923

Table 6. Results of multiple effects (UV + Water)

Code No	Average breakout force [gr]			
	Zero	15 days	30 days	45 days
UV + Water-1	2507	2233	1884	1609
UV + Water-2	2503	2209	1880	1650
UV + Water-3	2510	2253	1936	1655
Overall average	2507	2232	1900	1638
Rate of change of breakout force	1	0.890	0.758	0.653

Table 7. Results of multiple effects (Heat + Water)

Code No	Average breakout force [gr]			
	Zero	15 days	30 days	45 days

Heat + Water-1	2517	2194	1898	1569
Heat + Water-2	2509	2147	1874	1549
Heat + Water-3	2515	2164	1879	1606
Overall average	2514	2168	1884	1575
Rate of change of breakout force	1	0.863	0.750	0.626

Table 8. Results of multiple effects (UV + Heat + Water)

Code No	Average breakout force [gr]			
	Zero	15 days	30 days	45 days
UV + Heat + Water-1	2499	2129	1707	1404
UV + Heat + Water-2	2514	2077	1698	1437
UV + Heat + Water-3	2520	2082	1703	1420
Overall average	2511	2096	1702	1420
Rate of change of breakout force	1	0.835	0.678	0.566

The results of the experiment showed that within 360 hours, 720 hours and 1080 hours, U.V. radiation did not cause a significant loss of aderance on samples alone. This is due to the fact that the ready-made plaster used is pigmented and is especially connected to its thickness. The slight increases in aderance, which began to be seen after the first stage of 360 hours, were explained as polymerization continued after the 28-day waiting period and accelerated under the influence of U.V. radiation. after 720 hours of accelerated atmospheric conditions, fractures were observed during peeling experiments. This sequence shows that it begins to harden after a certain period of time under U.V. radiation.

In the samples where the temperature effect was applied alone, slight attenuation was detected in the measurements made after 720 hours. in the measurements made after 1080 hours, aderance losses were more pronounced. Since the temperature effect is applied in the form of heating and cooling repeats, it is understood that the stresses created by thermal expansion and shrinkage cause fatigue in the material after certain repetitions.

Wet-drying repetitions were the effects that led to the greatest difference in aderance from the first stage of 360 hours, out of these 3 parameters. After each stage, significant aderance losses were detected.

The most notable of the dual effects are the U.V.+ water effect and heat + water effect combinations. These combinations led to more loss of aderance than the combined effects of each factor making up the pair alone. For this reason, it can be said that in the process of associating climatic conditions with external degration, the duration of humidity is an important parameter. The results of the experiment, in which the binary parameters were applied, show that these two groups accelerated the influence of each other. However, when the results of all experiments are evaluated collectively with single experiments, it is understood that the main factor in aderance loss is the effect of water, while U.V. radiation and heating-cooling repeats create fatigue in the material and reduce its resistance to water effect even more.

Adherence losses were highest under triple effect. This is expected because the water effect was accelerated simultaneously by U.V. radiation and heat-cooling repeats.

4. Conclusion and Suggestions

The performance of the ready-made plasters used as a coating material in the face of atmospheric effects depends on the external environment conditions, the construction shell formation, the characteristics of the material and the application conditions. In connection with the external environment conditions, the duration of the surface to remain moist or wet is an important parameter in the external stability of the ready-made plaster, in connection with this, the healthy life of the material will be longer in ready-made plaster applications in the interior with low rainfall in which the terrestrial climate prevails, less evaporation, it can be said that the applications to be carried out in regions with high relative humidity are risky.

In the construction shell organization, ready-made plasters can be long life, the work to be done to prevent the transportation of water, moisture and salt when the plaster sublayers. For this purpose, it is necessary to choose the appropriate wall layers so that the condensation does not occur in the external wall sections, if the application is to be performed on a building surface that is still being used, condensation analysis is made, if condensation occurs, it is necessary to prevent this by adding steam cutter or heat insulation layers to the external surface. In addition, in applications made on the soil floor, terrace and surfaces in contact with wet places, it will be useful to prevent the transport of water by gate with waterproofing layers.

In the experiments carried out in order to have an idea of the behavior of synthetic (acrylic) binding ready-made plasters against atmospheric effects, U.V. radiation, heat and water effects and their double and triple combinations were investigated. Among these 3 parameters, which appear to be closely related, it is well known that temperature change and water effect are destructive elements for all materials in general. However, although the study was initially motivated by the prejudice that the material in question would suffer more damage than the U.V. radiation effect because it was an organic-based coating, experiments showed that this was not the case. As a result of the experiments, the following findings were obtained;

1. It has been observed that the effect of U.V. radiation alone does not have a sufficient meaning on the test sample used, that the pigmentation of the ready-made plaster and especially the layer thickness are effective in this behavior, and that a superficial degradation occurring in the upper parts of the layer does not lead to aderance loss.
2. As can be seen in Tables 2 and 3, it was understood that the main factor in the loss of aderance was water, that the water effect became more destructive with the effect of U.V. radiation and temperature change, and that the effect of U.V. radiation and the repetitions of heating and cooling (as they caused the resistance of the material against water to decrease) played an indirect role in the weakening of aderance that occurred in this process.
3. As can be seen in Table 3, if the experimental parameters act together, the destructive mechanism accelerates and creates a greater attenuation of aderance than the sum of the individual effects of each parameter.

In light of these results, the following can be said;

1. In order to understand the behavior of the material against physical environmental effects, it is important to examine the parameters together in similar studies to be conducted on this subject in the future. It is recommended that the separate examination of the parameters be done before examining them together and as a basis for this.
2. In order to make a realistic performance estimate, different test conditions should be created to simulate the physical environmental effects in a standard to be prepared for synthetic emulsion-based ready-made plasters used on exterior facades.

In addition to these parameters, it will be useful to investigate the effects of freezing thawing, acidic effect of air and salt parameters.

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The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study.

Author Contribution and Conflict of Interest Declaration Information

The article was written by a single author. There is no conflict of interest.

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