Test Device Developed for Sustainability of Material Use in Architecture

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***Abstract*—**This study aims to find a method to reduce the time of work needed while using preservative materials for restoration and conservation applications performed for the sustainability of historical buildings.

The durability of new polymer products need to be proven with accelerated wear-out experiments for the sustainability of worn out natural stones which are usually found in monuments. Using preservative materials on structure surfaces without laboratory testing usually results in irreversible mistakes. The need to practice accelerated experimental methods for the use of preservatives, with consideration of each work's natural stone texture and preservative material properties, has emphasized the importance of the simulation of accelerated wear-out factors and climatic data. The 'Preservative's Performance Test Device' that has been developed has made experiments easier in terms of time and application and, unlike others, has simulated the ground-soil effect on natural stone materials.

***Keywords*—** Sustainability, Historical Buildings, Materials, The Preservative's Performance Test Device

I. Introduction

Today, a number of methods that will minimise the external factors on masonry structures, especially those of historical buildings, are being researched. The materials used in historical monuments also need to be sustained for the sustainability the monument itself. Although the methods of applying preservative materials for sustainability of masonry materials of historical monumental structures in Istanbul are elementally the same, different preservative materials give a variety of results on different natural stones. Furthermore, some of the preservative applications have caused reactions in short periods of time, such as discolouration and textural deterioration of the natural stone materials; this is an undesired result, particularly for natural stone materials used in historical buildings. Therefore, to ensure desired results from the application, it is very important the preservative materials are tested in laboratories. A test device has been developed to facilitate multi-parameter experience methods and to save on time. The development of the device aims to test the performance of the preservative material under optimum laboratory conditions and within the shortest time. The Preservative's Performance Test Device can carry out experiments involving rain factors, sunlight factors (ultraviolet-infra red), groundwater-salt factors all at the same time or programmed to different times and can also measure the ambient temperature and relative humidity. The Preservative's Performance Test Device was the first of its kind in Turkey when it was developed; what makes it different than others in different countries is that it can simulate the soil-water-salt impacts that the stones are subject to. Experiments have compared the behaviours of stones that have and have not been subject to preservative applications. The preservatives used in the tests were silane and siloxane. The natural stone material used in the tests was limestone due to it being the main structural material used in most of the historical structures in Turkey, especially in monumental structures, and because it is not very durable against external factors.

II. Development and Working Principles of the Preservative's Performance Test Device (PPTD)

It is not possible to accurately measure the performance of preservatives required for the sustainability of historical structures with singular or duo test methods. In natural environments, structural materials can be subject to factors such as groundwater, UV and infra red rays, and soil water and salts at the same time.

Accelerated wear-out experiments that simulate natural environments in a laboratory should be carried out to accurately measure the performance of a preservative. Another reason to carry out such experiments is to demonstrate that different natural stones have varying durability with different preservatives. The mechanisms that impact the deterioration of natural stones can vary immensely. With consideration of all these reasons and to find a solution to the lacking points, a 'Preservative's Performance Test Device' was developed to simulate natural environments in a laboratory. The PPTD simulates:

Rain - water absorption

- Ultraviolet } sun rays
- Infrared
- Ground - soil factors (water absorption by capillarity + salt)

The device that has been developed allows the user adjust the simulations to any time or day and can simulate all the mechanisms that impact on the material one by one or all at once (Figure). The device can also measure the ambient temperature and humidity. When the PPTD is compared with other devices listed in literature, it is understood the principles of the device are based on the same foundation. The other devices use gas to simulate the atmosphere and categorize indoor and outdoor environments. PPTD's difference is that it provided ground-soil factors (water absorption by capillarity + salt).

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2.1 Preservative's Performance Test Device

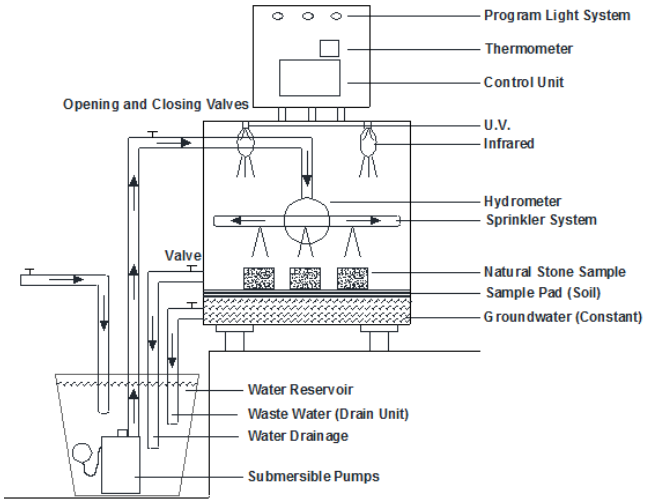

Fig.1. Schema of how the the Preservative's Performance Test Device works

Materials used in the device:

- Submersible pump (Nowax – Kika)
- Infra red 250 Xeroterm (Radium)
- Ultra-Vitalux 220-230 V-300 W (Osram – sun lamp)
- Control unit (Nelson-Smart Zone Ez)
- Felt (soil simulation)
- Thermometer (LCS8 Point Temperature Controller oC)
- Hydrometer (Pakkens Hygrometer %)

The control unit in use was originally built for an irrigation system however, it has been set to program the wear-out mechanisms as minutes, hours and days. The device's simulation periods can be programmed how and when desired. The submersible pump is used to pump water and the samples can be subject to water in any desired way. For the salt, a 10% Na2SO4 solution has been added to the water. The water level can be maintained at ground, soil or higher levels (for submerging) by closing one of the two discharge valves of the device. From above, sum factors, UV and infra red rays are simulated with lamps.

A number of test methods have been tested to accurately measure the performance of the preservatives; preservative was applied to 5 of the 6 surfaces of the sample and a natural environment was simulated.

Fig. 2. UV factor and infra red factor of the Preservative's Performance Test Device (S.O.Hattap)

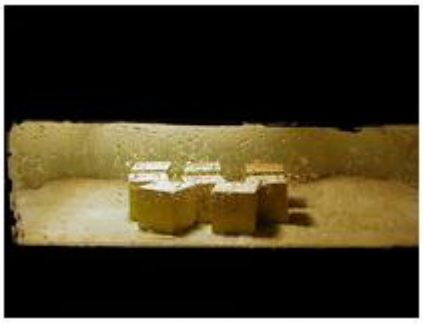

Fig. 3.Rain factor of the Preservative's Performance Test Device (S.O.Hattap)

2.2 Test Conditions and Climatic Data Correlations

While testing the performance of preservative materials, atmospheric factors need to be simulated so that the wear-out experiments be accurate. Meteorology terms atmospheric phenomenons as "meteorological elements".

The important point here is that the test conditions are in concordance with meteorological data. Tests carried out based on Istanbul province show that freeze-thaw factors are next to nothing compared to data of northern countries. However, rain and wetting-drying factors have a greater effect. The PPTD prioritises wetting-drying and sun ray factors. The ambient temperature and humidity was defined as an average of 23 oC and 65-70%, respectively.

2.3 Materials Used for the Tests

The preservative materials chosen for the tests were those preferred for applications: epoxy, acrylic, sliane and siloksane. The pretests showed that even though epoxy has very good water repellent and protective properties, it caused the colour of the natural stone turn darker. It was observed that even though acrylic emulsions were good for structural reinforcement, it does not have water repellent properties. Tests also showed that silane was only water repellent and didn't have structural preservation properties. Siloxane was chosen from among all the tested preservatives due to its water repellent and structural protection properties. While silane was preferred at first due to its water repellent properties, further experiment showed that it did not provide structural protection therefore, the tests were completed using siloxane only. The material chosen to be used in the tests is limestone; a natural stone which is used in most of our historical structures, especially in monuments.

III. CONCLUSION

Simulation tests were carried out in the Preservative's Performance Test Device based on meteorological data. All the samples used in the experiments were first brushed and washed with water, dried in a drying stove at 110 ・C ± 5 ・C to reach its fixed mass and then it was cooled to room temperature in a desiccator. The samples were weighed using 0.1 g sensitive scales (Precisa 4000 C –Swiss Quality) and then was subject to simulation tests in the PPTD. The ambient humidty and temperature were measured with the thermometer and hydrometer of the PPTD and the UV values were measured using a UV light meter UVA – 365 (Ultra – violet radiometer – Lutron UVA – 365 digital instrument)

After each of the test periods were completed, the samples were taken out of the device and weighed and after the experiments were completed, a few of the serial samples were submerged in water to see the salt factors, dried in a dryer oven, cooled in a desiccator and weighed.

All tests continued until the samples' saturation coefficient was reached and they started to decompose. As the natural stone used in the experiments were limestone and because this stone is naturally predisposed to rapid mechanic deterioration (especially from salt factors), the decomposition and breaking down of the stone started very rapidly. The tests have accurately proved the behaviours of samples with and without preservatives against deterioration mechanisms.

These studies and research have shown that the Preservative's Performance Test Device is very useful, especially for accelerated wear-out tests. It is very important that the materials used in historical buildings and that hold a very significant place in existing structural stocks are tested before being restored. As the PPTD is aims mostly for the smaller-scale producers (paint workshops, stone workshops, etc.) and because it is inexpensive and easy to transport, it is very useful in providing easily-applied solutions.

The concept of preservation should be approached as one structure that includes materials, structures and the environment, reducing probable environmental damages. It is difficult to monitor physical deterioration however, the precondition for ensuring material sustainability is taking steps to control harmful factors when chemical and biological impacts are present. Experiments carried out during the study emphasizes the responsibility of correctly defining deterioration mechanisms and laboratory testing before applying.

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