Monitoring of the State of St. Petersburg Stone Monuments and the Strategy of Their Preservation

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Abstract. The results of the multi-year monitoring of the state of Saint Petersburg stone monuments are summarized. The unique collection of decorative stones in museum Necropolis and the deposits that were most likely used to create them are studied. The processes of stone monuments' degradation in response to physical, chemical and biogenic influences are discussed. Special attention is paid to describing the monitoring methodology and the structure of the monitoring information database. Drawing on received results, the strategy for the conservation and restoration of monuments are discussed. The obtained data are of exceptional scientific interest in studying the processes of stone deterioration under the impact of the environment.

Keywords: Cultural heritage · Monitoring · Stone deterioration · Anthropogenic weathering · Restoration and conservation works

1 Introduction

Preservation of the monuments of cultural heritage is one of the priorities of the modern society. This problem becomes especially acute where the monuments are exhibited in the open air and subjected to destructive effects of the environment. In large cities, such as St. Petersburg, the deterioration of natural stone is notably fast, which is primarily due to the influence of the anthropogenic factor (The Effect 2019). Now we present the results of a multi-year, comprehensive study of the state of historical stone monuments of St. Petersburg, which are exposed to the destructive impact of the urban environment. The obtained data are of exceptional scientific interest for studying the processes of stone deterioration under the impact of the environment.

2 Methods and Approaches

Monitoring studies have been carried out in the Historical Necropoleis of the Museum of Urban Sculpture since 1998, where on a small square there is a unique collection of decorative and facing stone. The stone is intensively destroyed due to destructive

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influence of the volatile and humid Petersburg climate and unfavorable ecological situation. In this work, in addition to the Saint Petersburg scientists, museum staff and restorers, post-graduate students and students of the St. Petersburg State University, the Russian and Herzen State Pedagogical University took part. Over the past years, more than 1300 monuments of the Museum Necropolis have been examined (some of them several times), Based on the results obtained, a methodology for monitoring studies of stone materials of monuments was developed, which included the following steps: 1. Visual inspection of the object. Photographic documentation. Sampling. 2. Qualimetric evaluation of the integral state of the monument material (performed for 348 monuments). 3. Mapping of the types of material deterioration. 4. Examination of the samples of material and products of its deterioration by instrumental procedures (petrographic description of thin sections under a polarizing microscope, SE microscopy with EDX, X-ray phase analysis, biological methods). 5. Examination of the species composition of the microbial community on the surface of the monument. 6. Developing a 3D model of the monument and a quantitative estimate of the types of destruction of its material by the results of laser scanning. 7. Study of the local corrosivity of the air environment near the monuments. 8. Archival research. 9. Creating and maintaining a database on the state of the sculptural monuments in St. Petersburg.

3 Results and Discussion

Stone Material of Monuments. The diverse stone material in the museum Necropoleis is represented by marbles, limestones, granites and other hard rocks (gneisses, gabbroids, amphibolites, quartzites). The museum Necropoleis are not inferior to the historical center of St. Petersburg in the variety of stone. Basically, the stone came from Italy and the areas close to St. Petersburg (from the territory of the present Leningrad region, Karelia and Finland).

Qualimetric Evaluation of the Integral State of the Monument Material. The technique was developed jointly with V.M. Marugin (VITU, SPb). It was shown that the degree of stone destruction in the museum Necropoleis varies from 2 to 51%. In most cases, the extent of carbonate rock deterioration does not exceed 25% and that of granite and other hard silicate rocks - 10%. This is due to the considerable contribution of chemical weathering (formation of gypsum-enriched patina) in the deterioration of memorials of marble and limestone. Cracks occur on the surface of carbonate rocks that are heterogeneous in composition and structure (Ruskeala, Italian breccia and brecciated marbles, Pudost and Putilovo limestones) at least 10% more often than on other denser and more homogeneous marbles and limestones. But on denser solid silicate rocks (granites, etc.), cracks occur no less frequently than on carbonate rocks. At the same time, they are much more common (found on 80% of monuments) on such dense homogeneous rocks as Serdobol granite and Shokshinsky quartzite, which indicates a possibility of their anthropogenic or constructional origin. The incidence of the primary gypsum crust on the surface of limestones is more frequent than on the surface of marbles. Among limestones, the gypsum-rich patina is most often found on the surface of the porous Pudost travertine (on the surfaces of 50% of examined monuments). Among marbles, it

is most often seen on the homogeneous Carrara marble (on the surfaces of 26% of the surveyed monuments). Its detachment together with marble and the formation of a secondary gypsum crust are observed only on the monuments with a complex surface relief made of dense homogeneous marble: (white Carrara and light gray Bardiglio). In fouling, biofilms with dominant fungi are widespread on the surface of all rocks The input of microorganisms (fungi, algae, lichens) in rock deterioration varies from 2 to 10%. The degree of manifestation of various types of stone destruction significantly varies depending on the exhibiting conditions of the monument, the characteristics of the stone material, as well as the timing and effectiveness of work on the care.

Mapping of Deterioration Forms. Ultrasonic sounding was used to detect heterogeneities of the rock material invisible from the surface. Method for monitoring the biofouling of cultural heritage sites using computer technology allowing to register the areas of the most threatened biodeterioration sites was developed (Fig. 1). Beside 3D laser scanning method was used for to create 3D computer models and to carry out the quantitative measurements of various kinds of damage of the monument materials: cracks, chips, scratches, gypsum crusts (Fig. 2) and others.

Database on the State of the Sculptural Monuments of St. Petersburg. One of the most important stages in monitoring the state of the monuments was creating and populating a specialized database used to store, analyze and structure the accumulated factual information Currently, the database includes characteristics of the state of 650 stone monuments in the Necropoleis of the Museum of Urban Sculpture and in other parts of St. Petersburg.

Approaches and Methods of Monument Protection from Damage. To assess the effectiveness and safety of different approaches when removing biofilms, mud buildups and gypsum crusts from the surface of stone monuments, a comparative analysis was made of the potential of various chemical biocidal treatments and of laser cleaning options. The results of the experiments showed that the laser cleaning technology for removal of biofilms from the surface of the stone is comparable, and in some cases even superior to chemical treatment with hydrogen peroxide and kaolin. In the case of intensive development of biofouling, containing mosses and lichens, the efficiency of laser cleaning is significantly higher than the efficiency of chemical biocidal treatment. The use of laser cleaning to remove gypsum-rich patina is also effective.

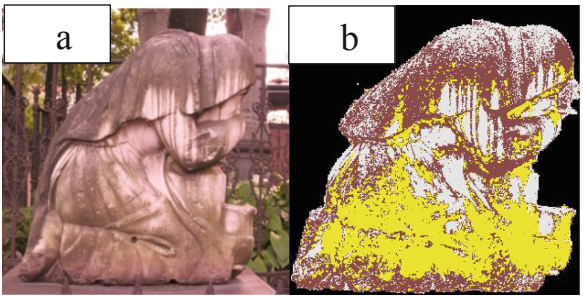

Fig. 1. Biofilms with dominant algae (color yellow) and dark-colored micromycetes (color brown): a-photograph, b-map

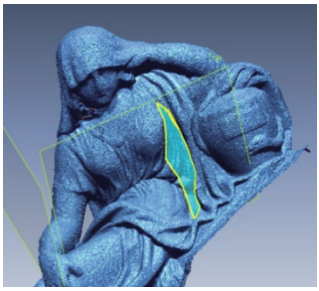

Fig. 2. Electronic 3D-model of fragment of the mourner sculpture, on which the area of the gypsum crust is highlighted

4 Conclusion

Integrated monitoring the state of St. Petersburg monuments provided an objective picture of the state of the their materials, makes it possible to take timely interventions for the restoration and conservation of works of art, to plan the necessary measures to protect the stone from deterioration and in result make it possible to preserve and adequately exhibit the works of monumental sculpture and memorial art of St. Petersburg, which are an impressive, imaginative part of the world history and culture.

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