

ENVIRONMENTAL INFLUENCE ON STONE DAMAGES OF THE MONUMENT “OSLOBODIOCIMA BEOGRADA 1944” (SERBIA)

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The monument “Oslobodiocima Beograda 1944” is located in a highly polluted district of Belgrade, about 1.5 km southeast from the center of town. All surrounding streets have heavy traffic virtually throughout the day, which results high atmospheric (SO_2 , CO_2 , NO_x) and acoustic pollution around the monument. The city has a typically medium continental climate with wet and hot summers, and long cold winters, often with fog and snow. Average yearly precipitation, number of frosty days and high relative humidity in winter undoubtedly accelerate the degradation of sandstone and limestone. The yearly average pollutant concentrations are relatively high, with yearly maximum average above the sanitary limits in Belgrade. SO_2 in the air changes the pH of rain. These acid rains attack stone blocks. During the last ten years, contents of SO_2 and smoke show a descending trend, but even their lower contents are pernicious for rocks.

The monument was built in 1954. The main portal, platforms and steps were made of sandstone blocks and the base-reliefs of limestone. Forms of weathering observed on the monument were: exfoliation, cracking, grain disaggregation with loss of reliefs. The particular types of deterioration of the stone are black crusts and the appearance of efflorescence along the mortar joints of sandstone blocks and on the surfaces of base-reliefs built of limestone.

The data of X-ray diffraction show that the efflorescence consists essentially of halite [NaCl], thenardite [Na_2SO_4], apthitalite [$(\text{K},\text{Na})_3\text{Na}(\text{SO}_4)_2$] and gypsum [$\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$].

The black crust, a typical weathering phenomenon on buildings in urban areas, is formed on the block surfaces that are not exposed to rain influence. They are composed of gypsum mixed with soot particles. Blistering and peeling off of the crust cause disintegration of stone surface.

Halite is originated from streets salted during winter. SO_2 from the atmosphere affects the surface of limestone and sandstone containing CaCO_3 as a binder as well as the mortar between blocks. When sulfur compounds are adsorbed on the stone surface or along joints of blocks, a series of reactions begin and gypsum is generated as end product. Na and K (thenardite and apthitalite) probably derive from air pollution or the material of the mortar.

The rate of stone decay is effected by a number of factors, both natural and man-made, of which humidity, temperature and atmospheric (urban) pollution are the most important as well as superficial working of stone blocks. The obtained results suggest that the main causes of sandstone decay are water and frost, but also important are the sulfur compounds precipitating from atmospheric pollutants.