

# Strengthening the historical constructions made of limestone by treating with silicic acid based material

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**Abstract:** The paper a comparative study of limestones treated with the composition Oxal NK100 for increasing the durability of the limestones in historical buildings and the other limestones without any additives to investigate the effect of the composition Oxal Nk100 on the durability of the investigated stones. Results of frost resistant test and compressive test of different samples are included and analyzed . Indicators charts and diagrams are given included and explained.

## Introduction

Despite its internal strength, limestone belongs to the type of soft rocks. Limestone products begin to collapse on average 75 years. The experience showed that different constructions and various structures of historical buildings in the Crimean republic begins to collapse within 200-400 years. The reason for the destruction is the high humidity affecting the constructions in the mentioned region beside other external factors. Subsequently, the chemical decomposition of minerals and dissolved in water acids. The stone is leached, cracks and cavities begin to form leading to decrease the strength and the stability of the rock. When the water starts penetrating the cavities limestone softening. In this situation, it is important to find the right methods and materials that extend the life of historical constructions and offer ways to strengthen structures by performing repair and restoration works without violating the historical reliability of the facades. The authors of VN. Alekseenko and O.B. Zhilenko developed recommendations for strengthening the load-bearing structures of the monument of architecture - the church of St. Archangel Michael in Sevastopol [1]. Various modes of destruction of porous limestone samples and their corresponding deformation curves were investigated [2,3]. In Russian Federation, there is an active development of the construction industry, in this regard, many authors are considering the introduction of their own resources in the manufacture of building materials. Different constructional materials are explored in the work of different authors [4,5,14,6–13].

At the moment, the actual topic of the research is the durability of building materials and structures. Consideration is given to such aspects as the safety of structural materials in time, the service life of the material after its treatment with various compositions after a long or short-term exposure to the material by all sorts of external factors [2,14–23].

## Methods

Oxal NK100 is a stone stabilizing compound for natural stones, bricks and terra cotta, suitable for mineral and absorbent materials. This impregnation is created for the reconstruction of architectural monuments and increasing the durability of their materials

Different samples of a stone from nummulite limestone are examined and compared with the same limestone impregnated with the stone-strengthening composition Oxal NK100. The tests were carried out on samples of the size:  $a = b = c = 50$  mm (with an error of  $\pm 2$  mm). Samples in accordance with the terms of reference were marked in color and numbered depending on the test and the type of samples.

In order to obtain performance specifications, two different types of tests were carried out to examine the effect of the Oxal NK100 composition on the different properties of the treated limestone. All tests were carried out in accordance with Russian standard GOST 30629-2011 "Materials and products facing from rocks. Test methods »[20].

The ultimate strength is calculated as the arithmetic mean of the test results when five specimens are compressed on a hydraulic press.

The essence of the method for determining the frost resistance is to obtain the loss of the material strength under investigation after a specified number of cycles of alternating freezing and thawing compared to the strength of a water-saturated sample that has not undergone freezing. The loss of strength of the samples is calculated as the arithmetic mean

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of the results of each five samples after (15; 25; 35; 50) and every subsequent 50 cycles of alternate freezing and thawing of five water-saturated samples are subjected to a compression test.

## Results and Discussion

The ultimate strength of each type of samples in the water-saturated state was determined during the compression test, and the arithmetic mean value of the tensile strength was calculated. The ultimate strength of each type of samples in the dry state  $R_c$  was also determined during the test, and the arithmetic mean value of the tensile strength was calculated. Based on the results of the arithmetic mean values, a comparative diagram of the samples in two states were drawn as shown in figure (1).

After compression tests, five samples of each type were subjected to a frost resistance test. After a given cycle period, then the samples were tested subjected to the compression test.

The limestones samples which were not treated with Oxal NK100 (natural samples) showed visible defects after 30 cycles of alternating freezing and thawing, the continuation of the frost resistance test was suspended due to the inexpediency of the test while the samples which treated with Oxal NK100 has reached 50 cycles in order to notice alternative visible defects. Furthermore, the strength of the limestones treated with Oxal NK100 was increased as shown in the figure (2).

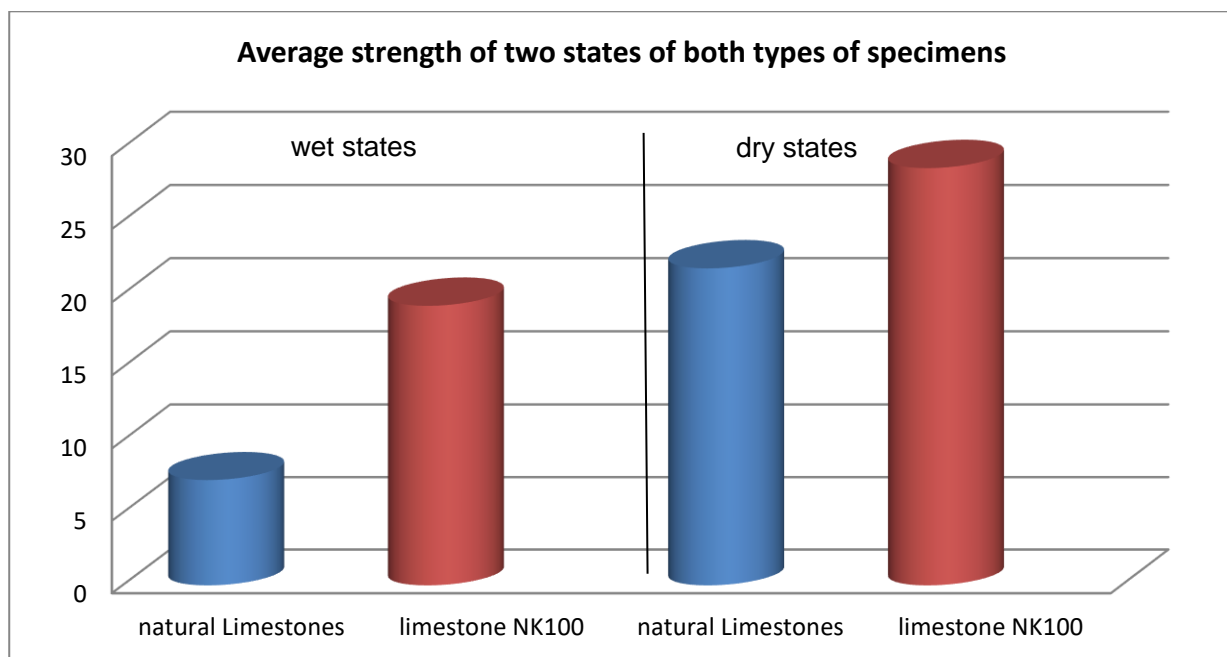


Fig. 1. The average strength of natural limestones and the limestones with additives NK100 in both dry and the wet states

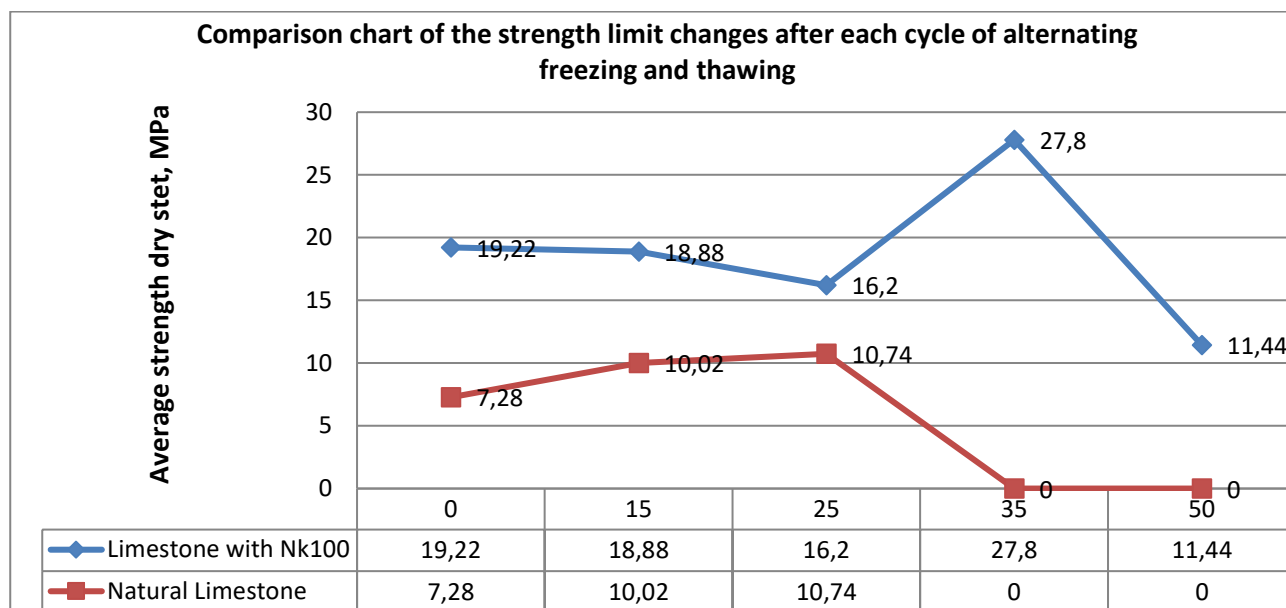


Fig. 2. The graphs of the changing in the strength limit after each cycle of alternating freezing and thawing according to the frost-resistant test results for the natural limestones samples and the samples treated with the composition Oxal NK100

### Conclusions

The limestones impregnated with stone-strengthening material Oxal NK100 showed a result in which, the reduction in strength in the water-saturated state is less than that of limestones in a similar state without impregnation.

The limestones without treatment could withstand only 25 cycles, and limestone treated with stone-strengthening composition after 35 cycles of alternating freezing and thawing strongly loses its strength but withstands frost resistance up to 50 cycles. Consequently, it can be concluded that limestone treated with Oxal NK100 material can withstand twice than the natural samples (without treatment) of alternating freezing and thawing according to the results of the comparative test showing the increases of the treated stone durability.

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