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Durability of Enclosing Structures by Means of Using Lime *Short communications*

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Abstract: The problem of the durability of construction materials and engineering structures has always been and remains relevant. This parameter depends on many factors that daily effect the construction material such as operating conditions, temperature, precipitation, aggressiveness of the environment, and density. The issue of durability is especially relevant for bridges. The main role in the preservation of materials over time and durability is played by a binder on the basis of which they are made. Today, on the territory of Ukraine, there is a fairly large number of structures built in the 19th and early 20th centuries, where lime was used as a binder. Studying the construction materials from the Collegium building by Pavlo Galagan in Kyiv, it was revealed that the outer walls and foundation were authentic. As a result of the research, it was found that materials based on lime binder had high durability, despite the fact that they were used in an aggressive environment. The high durability of lime binders and materials that have lime as a base allows us to advice, after appropriate justification, the use of lime in enclosing structures, in cases where high strength is not required.

Keywords: lime, brick, masonry mortar, durability

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1. Introduction

The durability of the material lies within its properties to maintain its operational state (workability) and perform the required functions until its limit state occurs, taking into account the maintenance and repair system applied to it.

The problem of durability of construction materials, buildings, and structures, in particular, has always been and remains relevant. This parameter depends upon countless factors that affect the construction material on a daily basis, which are operating conditions, temperature, precipitation, environmental aggressiveness, material density, etc. The issue of durability is of special relevancy for enclosing structures.

The binder happens to play the main role in the safety of materials over time and their durability as it is used as a basis to produce them [1].

2. Durability of Enclosing Structures by Means of Using Lime. Result of the research.

Nowadays, materials that mainly utilize the Portland Cement are widely used as a binder. In the course of hardening, these materials are characterized by the formation of calcium- based hydrosilicate compounds, which are quite durable. Their chemical composition and structure corroborate their durability as they are similar to natural compounds that have existed in the natural environment for thousands of years [2]. Therefore, materials based on Portland Cement are quite durable, provided that they are used professionally and in a timely and proper manner.

That said, there are materials based on other binders, which are lime binders, in particular. Lime binders have been used in construction for thousands of years. Well-known bridge structures, for example, viaducts had been built in Ancient Rome before our era, using lime binders. The interweaving of calcium hydroxide crystals and its subsequent carbonation make the hardening of this material happen, with the carbonate compounds formed. With active mineral additives available in the binder, they interact with lime forming calcium hydrosilicates. Even before the beginning of the 20th century, Portland Cement was not in wide use in the construction industry. But lime and lime-based binders were widely used to manufacture construction materials and, in particular, masonry mortars.

To date, in Ukraine, there are a fairly large number of buildings and structures built in the 19th century and early 20th century, using lime binders. Currently, for such structures, the issue of their durability is quite acute.

For instance, the Halahan Collegium building was built in Kyiv in the second half of the 19th century. At that time, Portland Cement did not come into being yet. The state has the building registered as an architectural and historical monument of local significance [2]. Thus, the issue of the durability of its structures and original appearance remains relevant to this day.

Upon study of construction materials of the Halahan Collegium building in Kyiv, it was found that its exterior walls and foundation were authentic.

The study of the colour on the depth of ceramic bricks, removed from the wall of the courtyard facade, showed that the bricks were of a yellow colour, which indicates they contained lime and had a low content of iron in the raw material, which was typical for bricks produced in Kyiv in the 19th century. The brand on the bricks shows that the bricks were produced at a factory owned by Yakiv Berner. The bricks have no significant external signs of deformations and defects. The bricks are 26.6 cm x 13.3 cm x 7.0 cm as prescribed by Emperor Nicholas the First in 1847. Such dimensions and branding of bricks are typical for products made in the late 19th century and early 20th century. Modern brick dimensions, which are 25.0 cm x 12.0 cm x 6.5 cm, were established in the former USSR only in 1927. Testing of the bricks and their appearance showed that their operational properties did not impair and they can still be used in structures.

The current state standards stipulate that lime-sand mortar should have a compressive strength up to 0.7 MPA on the 28th day of hardening. No increase in the strength of the mortar during the hardening period of more than 100 years may indicate that the mortar does not contain active mineral additives (opoka, rotten stones, ground bricks, etc.) [4], since such additives interact with lime and increase the strength of the mortar. Therefore, the hardening of lime-sand mortar of masonry is due to the fact that the resulting calcium hydroxide crystals intertwine with each other and create a bond that forms the masonry mortar. Over time, calcium hydroxide is carbonized to form the corresponding carbonate. Its crystals fuse together, as well as intertwine with sand and $\text{Ca}(\text{OH})_2$ residues. In the course of carbonating $\text{Ca}(\text{OH})_2$, a larger volume of the solid phase is formed, which causes the mortar to compact. In addition to carbonate, compounds such as $\text{CaCO}_3 \cdot n\text{Ca}(\text{OH})_2 \cdot m\text{H}_2\text{O}$ can be formed.

A layer-by-layer study of the structure of the existing plaster walls (stratigraphic analysis) facilitated determining the initial state of the building's facade. For instance, it was found that the original surface of the brickwork of the courtyard facade was not plastered. It is worth mentioning that the bricks were painted in red (ochre) colour with a limestone composition.

Consequently, lime-based materials are quite durable and retain the density of their structure and strength for a long time.

The study of the moisture of construction materials of the facade made of lime-based materials (brick, masonry mortar) revealed that the percentage of moisture visually increases from the roof to the basement of the building, as the materials of the basement and the walls above it have signs of destruction and soaking, which affected the durability of these materials eventually [5]. As of today, the lack of high-quality waterproofing of the facade and blind area causes the facade to soak and its plaster to peel off. Nonetheless, these operating conditions have failed to impair the high durability of lime mortar.

3. Conclusions

The results of the conducted research demonstrate that lime binder-based materials are of high durability despite the fact that they are used in an aggressive environment represented in polluted air that contains an increased content of carbon, heavy metals, etc., which are characteristic of large cities. This is confirmed by the studied masonry mortar, which is represented by a mixture of lime mortar and sand used to build a house in the 19 century in Kyiv.

The high durability of lime binders and materials based on them allows us to recommend their use in enclosing structures upon appropriate justification, in cases where high strength is not required. It is shown that ceramic bricks have a high durability. Therefore, they can be recommended for use in enclosing structures upon appropriate justification.

In order to operate structures built using lime binders, further monitoring of their condition is recommended.

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