PROTECTION METHODS FOR APARTMENT BUILDING FOUNDATIONS AGAINST AGGRESSIVE INFLUENCES IN COMPLEX URBAN ENVIRONMENTS

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Abstract: In urban areas characterized by complex hydrogeological conditions, the rise in groundwater levels coupled with their aggressive chemical composition exerts a severely adverse impact on the structural strength of multi-family residential building foundations. Chloride ions present in the groundwater initiate reinforcement corrosion within the reinforced concrete structures, inducing internal stresses that lead to structural cracking and macro-fissure propagation. Concurrently, sulfate ions trigger the degradation of the cement stone, significantly accelerating the process of sulfate attack (sulfate corrosion). Consequently, under conditions of dense urban fabric and highly developed infrastructure, identifying ecologically sound and economically viable methods for strengthening the foundations of operational multi-family residential buildings constitutes a critical task in contemporary urban development and engineering.

Keywords: multi-family residential buildings, technical condition, foundation deformation, aggressive groundwater, chloride ions, sulfate corrosion, foundation injection, innovative method, engineering solutions in urban planning, durability of structures.

INTRODUCTION Throughout their operational lifecycle, the structural components of buildings and civil engineering works are continuously subjected to a diverse array of anthropogenic, natural, and technogenic stressors. In particular, foundation structures which bear the entire superimposed dead and live loads of the superstructure and safely transfer them to the underlying strata permanently execute their load-bearing functions under the continuous exposure of localized, complex, and aggressive environmental impacts. Under such environmental regimes, the kinetic rates of physical degradation and structural wear across various structural elements manifest heterogeneously. For instance, complex local hydrogeological conditions can induce adverse structural and mineralogical transformations within the sub-foundation soils, potentially triggering uneven differential settlements due to the sustained geostatic and structural loads acting upon the ground. Consequently, one of the most paramount imperatives of contemporary urban planning and engineering is ensuring the structural safety, seismic resilience, and long-term durability of the aging multi-family residential housing stock. Corrosion and physical deterioration of materials can be sharply accelerated under the influence of aggressive environments in the construction of buildings in areas with high groundwater levels, high salinity and mineralization, and

engineering-geological and hydrogeological conditions [2].

METHODOLOGY One of the main engineering problems in urban planning for the long-term safe operation of multi-apartment residential buildings and their reconstruction is, of course, the uneven settlement of the foundations of buildings (soil base). Deformations in the soil and foundations lead to the appearance of dangerous stresses in the superstructure (load-bearing walls, frames and enclosing structures) of the building, the formation of cracks and fissures, which can ultimately lead to the collapse of the structure.

The following are the main reasons that lead to the subsidence of foundation structures due to the above-mentioned factors that negatively affect buildings: *Hydrogeological factors:* sudden changes in the groundwater level, changes or deterioration of the physical and mechanical properties of the soil as a result of the rise of groundwater to a critical point, which negatively affects the strength of foundation structures.

Technogenic and structural factors: actual loads exceeding the standard loads due to the construction of additional floors (increasing the number of floors) or the installation of heavy equipment (violating the functionality requirement) during the use of buildings; large-scale construction and installation and earthworks (pile foundation construction) carried out in neighboring areas.

Specificity of soil conditions: spontaneous subsidence of soils in the area, karst areas, loess and silty soils due to wetting.

Subjective factors (defects and errors at the design and construction-assembly stage): incorrect determination of the geometric dimensions and depth of the foundation, insufficient testing and acceptance of the soil's bearing capacity. All of these factors lead to deformations in the foundations and walls of buildings.

DISCUSSION In order to reduce the level of physical deterioration of buildings and ensure their durability, it is necessary to conduct timely instrumental inspections and use modern restoration technologies during the exploitation period [5].

If the instrumental inspection of the foundations of multi-apartment buildings does not show sufficient load-bearing capacity, the following engineering methods can be used in urban planning to strengthen the foundations, prevent and stop subsidence:

Installation of pile foundations under an existing foundation: inserting additional pile foundations under or next to the existing foundation of the building, placing pile foundations to deeper, more solid soil layers by drilling. Expanding the geometric dimensions of existing foundations: spreading the load on the soil over a larger area by expanding the area under the foundation with a reinforced concrete structure (reducing pressure).

These methods can be considered simple but labor-intensive and technically demanding approaches. When a project is implemented through such methods, it can cause harm not only to the residents living in this building, but also to the residents living in a particular residential area (it can damage the infrastructure of the area, create inconveniences in the movement of residents, negatively affect the microclimate of the area, and when equipment is operating, it can negatively affect human health and create noise levels.

exceeding the permissible (55 dBA during the day) [1].

In order to prevent such inconveniences for the population and the microclimate of the area, there is a more modern and convenient approach compared to these methods, which is the following method: *Cementing and strengthening the foundation base:* reducing the porosity (densification) and increasing the strength of the foundation by injecting a special chemical or cement mixture into the soil under high pressure, with this method, when implementing the project, it is possible to carry out almost all the processes from the basement of the building. If performed in buildings without a basement, it is characterized by the fact that this work does not require the use of large equipment and does not result in a high noise level. This method can be considered an innovative approach to strengthening the foundation, when injected into the soil under the foundation, it is achieved not only to strengthen the structure, but also to reduce the aggressiveness of chloride and sulfate ions in the groundwater of the foundation.

Effect of chloride ions (Cl^-) on the structure: these chemicals do not have a direct aggressive effect on the cement stone of concrete, but rather accelerate the corrosion process of the steel reinforcement inside it, which ultimately leads to the appearance of cracks and fissures in the concrete due to the increase in the volume of corroded reinforcement [3] (Figure 1).

Figure 1. The effect of moisture (chloride ions) in the basement of a building on reinforced concrete structures.

Effect of sulfate ions (SO_4^{2-}) on the structure: unlike chloride ions, sulfate ions directly chemically decompose the cement stone of concrete, a process called “sulfate corrosion” [4].

Sulfate ions react with components in concrete, causing significant volume expansion, increased crystallization pressure, and structural degradation of cement stone [6].

Conclusion. The analysis of the complex of hydrogeological, technogenic and subjective factors that cause deformation of the foundations of multi-apartment residential

buildings within the framework of the study shows that the rise in the level of groundwater to a critical point and the specificity of the soil conditions pose a direct threat to the strength of buildings. In particular, the acceleration of corrosion of reinforcement by chloride ions contained in groundwater and the erosion of cement stone by sulfate ions (sulfate corrosion) sharply reduce the service life of structures. When comparing the advantages of engineering and modern innovative methods implemented to prevent these situations, the method of cementing the foundation base and injecting it using chemical mixtures is considered the most effective innovative approach in urban planning.

This method prevents environmental and acoustic inconveniences, since it is carried out without large-scale equipment, mainly from the basement of the building. Most importantly, the injection of special substances into the foundation base under high pressure not only increases the bearing capacity of the soil and reduces porosity, but also forms a waterproofing barrier that protects the foundation body from the ingress of aggressive hydrogeological environments (chloride and sulfate ions). The use of injection technology to extend the service life of apartment buildings in urban areas with complex hydrogeological conditions is the most optimal engineering solution from both an economic and ecological and social point of view.

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