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Retrospective analysis of wall waterproofing structures to determine the main directions of the relevant restoration work

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The rationality of foundation and plinth construction largely depends on soil moisture, which is influenced by groundwater levels, precipitation, site grading, the quality of near-wall paving, and the use of hard landscaping. To determine effective structural solutions that prevent plinth dampness, a retrospective analysis of plinth designs across different historical periods was conducted. The study covers the mid-19th century to the present — a timeframe marked by major socio-economic changes and technological progress. The analysis revealed that before 1953, domestic construction lacked mandatory waterproofing standards due to the absence of mass-produced materials. Since 1956, with the shift to industrial construction, standardized waterproofing methods using mass-produced materials were introduced. Today, particularly in the context of reconstruction and restoration, local waterproofing challenges require tailored, site-specific solutions. The study underscores the importance of adapting historical experience to modern construction needs, ensuring effective moisture protection of wall foundations and plinths.

Keywords: waterproofing; foundation; plinth; historical buildings

Ретроспективний аналіз конструкцій гідроізоляції стін для визначення основних напрямів відповідних реставраційних робіт

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Раціональність конструктивного рішення фундаментів і цоколів будівель залежить від кількості вологи у ґрунті. На неї впливають: рівень ґрунтових вод, атмосферні опади, якість вертикального планування прибудинкової території, якість виконання будівельних робіт при формуванні вимощень у пристінній частині будинків та наявність твердих покриттів у благоустрої прибудинкової території. Для визначення раціональних конструкційних рішень, що перешкоджають зволоженню цокольних частин будинків було проведено ретроспективний аналіз варіантів конструкцій цоколів будинків у різні часові періоди. Розлянуто період з середини Х1Х століття до наших часів, адже у цей період відбулося у будівництві ряд змін, пов’язаних з соціально-економічними перетвореннями у суспільстві та значний науково-технічний прогрес. Внаслідок ретроспективного аналізу конструкцій гідроізоляції прифундаментних частин стін встановлено, що до 1953 року у вітчизняній практиці будівництва була відсутня обов’язкова вимога влаштування такої гідроізоляції через відсутність масового виробництва відповідних матеріалів. З 1956 року з переходом будівництва на індустріальну основу, були напрацьовані як типові варіанти гідроізоляції стін з використанням матеріалів, що масово вироблялися. В сучасних умовах практики будівництва, особливо у таких напрямках як реконструкція і реставрація, необхідно використовувати індивідуальний підхід для вирішення локальних проблем гідроізоляції стін будинків.

Ключові слова: гідроізоляція; фундамент; цоколь; історичні будівлі

Introduction

When surveying buildings, special attention should be paid to the part of the walls that are in the zone of the greatest influence of moisture and temperature - the plinths of buildings. After all, it is located in the zone of active moisture during rains, since part of the liquid precipitation from the roof of the buildings, even with organized drainage, overflows beyond the roof and falls on the pavement near the wall and splashes moistens the plinth from the outside. The plinth also receives some of the water that runs off the wall surface during slanting rains. Another factor of moisture can be improper planning of the territory where the house is located. If the ground surface slopes towards the house, excessive moisture accumulates near the wall, both on the soil surface and below the surface, which also contributes to the moistening of the plinth. The above options for moisturizing can be called surface contact.

Another option for moistening is capillary moistening. The plinth is located directly on the foundation, which is immersed in the ground to its full height. The humidity of the foundation depends on the amount of moisture in the soil, as well as the properties of the materials of these parts of the house, namely, porosity, which create conditions for the movement of moisture towards the basement. The rationality of the design of foundations and basements depends on the amount of moisture in the soil. And it is influenced by the groundwater level, rainfall, the quality of the vertical layout of the adjacent territory, the quality of construction work in the formation of blind areas in the wall part of the buildings and the presence of hard coatings in the improvement of the adjacent territory.

In buildings that are more than 100 years old, the foundations and basement are made of brick, so they are constantly wet. Over time, this has led to frost damage to the relevant structures.

To determine rational structural solutions that prevent moisture in the basement of buildings, it is worthwhile to conduct a retrospective analysis of the options for building basement structures in different time periods. The period from the middle of the nineteenth century to the present day is appropriate, since during this period a number of changes occurred in construction related to socio-economic transformations in society and significant scientific and technological progress.

Review of the research sources and publications

The problem of waterproofing building structures has been known for a long time [1] and is constantly being studied. Moisture and water in building structures are the subject of numerous studies [2-3]. The issue of waterproofing is important for the preservation of historic buildings [4-6]. The results obtained in such studies are used to develop practical recommendations for waterproofing building structures [7-8].

Definition of unsolved aspects of the problem

The restoration of historic buildings does not pay attention to the causes of moisture in the brickwork of the foundations and plinths, which results in frost damage to the bricks from the outside and mold formation inside the walls. Therefore, repair measures include only the replacement of the interior and exterior finishes of the wetting wall sections. This leads to their repeated destruction over a larger area.

Problem statement

The purpose of the publication is to investigate the specifics of the operation of historic buildings through a retrospective analysis of the design options for building basements in different time periods and to identify the main measures to restore waterproofing in their foundation zone.

Basic material and results

Since the mid-nineteenth century, three types of objects have been used in urban development on the territory of Ukraine, which at that time was part of the Russian Empire: mass housing, "elite" housing, and public buildings. Poltava was not spared from this practice of construction. The first two groups of objects listed above were different in terms of their functional features and materials used in their construction. Mass housing was small in size and had compact space-planning solutions. Such houses were built using a wooden rack and beam system with the frame filled with clay-sand mortar or clay concrete. Sometimes adobe was used. This is evidenced by the large number of old one-story houses in Poltava with this construction solution (Fig. 1).

Near such housing, as a rule, there are " lordly" houses, near which even outbuildings such as carriage sheds, barns, and cellars have been preserved. The second type of housing is structurally different from mass housing. The foundations, plinths, and the outer layer of the exterior walls are made of brick. The inner layer of the outer walls is made of wooden beams, approximately 200x200 mm in size. Attic floors in both types of houses are wooden (Fig. 2).

The third type of buildings, public buildings, built from the mid-nineteenth to the early twentieth century, have brick walls with lime mortar. Brick was then used in the construction of foundations, basements, and the bulk of not only the exterior and interior walls, but often in the construction of floors in the form of vaults and staircases based on arched structures. A striking example of such solutions is the Cadet Corps building in Poltava (Fig. 3).

The bricks made during the period under consideration differed from those used in modern construction practice. Thus, its dimensions were as follows: thickness was 67 mm; width - 134 mm (two thicknesses without a seam); length - 268 mm (two widths without a seam) [9].

Figure 1 - Residential buildings using a wooden frame with clay-sand mortar or clay concrete filling

Figure 2 - Residential buildings with brick walls and foundations

Figure 3 - Public building with brick walls and foundation

The brick-making technology also differed from the modern one. For example, clay was frozen and soaked for 3-4 days. This was followed by kneading the clay, and then forming bricks in wooden molds by hand-packing [9]. According to N. Fadeev [9], this technology of brick making using prolonged soaking of clay and its kneading before molding contributed to a decrease in the water permeability of bricks. A tangential proof of this is the practice of preserving damage to such garden and park objects as retaining walls, stairs by pouring crushed clay into cracks to prevent water and debris from entering the damage sites, as well as well-known recommendations for creating waterproofing layers near the foundations of crushed clay. In order to obtain indisputable evidence of the possibilities of using ancient bricks to protect walls from capillary moisture, it is necessary to study in the future the change in brick properties depending on the peculiarities of its manufacturing technology.

When inspecting the structures of the ground parts of the walls of all the above types of buildings built before the 30s of the twentieth century, it was found that there is no horizontal waterproofing between the foundations and the basement parts of buildings using special waterproofing materials. Obviously, there is a functional need for waterproofing, but there are no appropriate construction solutions using special waterproofing materials. Or this problem was partially solved by using bricks with high resistance to water penetration.

In professional literature sources of different years of publication, the theory of using horizontal waterproofing in the ground part of the walls of buildings is given a different amount of attention. For example, in the 1930 edition of the manual for technical schools authored by N. Fadeev [9], in the section on masonry work, the performance of work in the construction of brick walls is considered in detail. But there is no information about the waterproofing device. The figures showing a section of the outer wall do not show the location of the waterproofing. One could conclude that the issue of moisture protection of building walls is not addressed. However, the section on building adobe walls focuses on the installation of waterproofing: "If there is a possibility of soil dampness, which is especially harmful to adobe, then a layer of roofing felt, birch bark, or other similar material is laid on the foundation under the walls themselves." To protect the adobe wall from rain and snow water, it is not recommended to use a protruding plinth. It is recommended to build a wall of adobe so that its plane coincides with the plane of the foundation or plinth. From this we can conclude that in the practice of construction until the 30s of the twentieth century, the influence of moisture on the wall structure, namely its basement, was taken into account, but to protect against it, wall and foundation materials with minimal hygroscopicity at that time were used.

As for the mass housing, it was protected from moisture in the ground part of the walls by using "pryzby", which was a thickening of the lower part of the wall to a height of 500-600 mm (Fig. 4). The "pryzba" traditionally protruded 400-500 mm from the wall plane and served as a pavement that diverted rain and snow water from the adobe walls and as insulation for the ground part of the wall. This element of the house is an element of folk national architecture, so the peculiarities of their design solutions are not discussed in detail in the professional literature, since the methods of folk construction are not a component of the formation of the ideology of construction industrialization, which had already begun at the time under consideration.


Figure 4 – Residential building with a "pryzba"

Since the 30s of the twentieth century, significant changes in all areas of construction activity have begun. A system for standardizing the parameters of building materials was created. Thus, the governing bodies of the national economy decided to standardize the dimensions of bricks: length - 250 mm, width - 120 mm, height - 65 mm [9]. New building materials appeared with their detailed descriptions in the professional literature, especially after 1945. Taking into account the peculiarities of the historical period, a large amount of reference literature is published, for example, reference books [10], [11]. Regulatory documents are being adopted, such as the "Technical Specifications for the Performance and Acceptance of Construction Works" [12] and the like.

In the reference literature of 1950 [10], it is recommended to use various types of roofing material for waterproofing. The reference book of 1955 [11] also lists roofing felt as a waterproofing material with different markings and recommended purposes. A common feature of both of these publications is that neither of them contains recommendations for the use of rolled waterproofing in walls. Only as a roofing material for roofs.

Strict requirements for the installation of protection against soil moisture of foundations and ground parts of walls appeared simultaneously with the introduction of technical conditions for the performance and acceptance of construction work, which were adopted in 1953 [12]. The section "Works on the Installation of Waterproofing" in the part "Waterproofing of Walls" contained a list of mandatory works to protect walls and pillars from capillary moisture.

Cement-sand mortar (with a ratio of at least 1:2) in the upper part of the foundation or in the lower part of the wall; coatings based on black binders; cast asphalt, rolled materials in one layer or in several layers, interconnected with bitumen (black) binders "with significant soil moisture" were recommended as waterproofing materials.

The technical conditions strictly limited the location of horizontal waterproofing in exterior walls - not lower than 10 cm from the level of the pavement or sidewalk. For interior walls - not lower than the upper level of preparation for floors [12].

Since 1956, construction in Ukraine has been in a state of maximum industrialization, meaning that all types of architectural and construction activities were clearly regulated. Information and regulatory professional publications were centralized. Construction according to standard projects developed by central research and design and experimental institutes gained significant momentum. In parallel with the development of unified and standardized space-planning solutions, unified options for protecting the foundations and basements of buildings were developed, based on two main structural solutions - the use of coating waterproofing with hot bitumen in 2 times, as well as the use of rolled waterproofing of two layers of roofing material in various variations. Such waterproofing options were presented in almost all textbooks and manuals for the professional training of architects and builders.

This put an end to the use of ambiguous options for waterproofing the ground parts of the walls of buildings, the volume of construction of which, due to industrialization based on the unification and typification of design, construction, production of building materials and structures, reached huge volumes in the 60s-80s of the last century. An example is the emergence of such neighborhoods as Almaznyi, Polovky, Levada, Sady-1, Sady-2, and Ognivka in Poltava during this period. During this period, Poltava's development was actually divided into two parts:

1) the old city, created by the buildings of the nineteenth and first half of the twentieth century.

2) the new city, created by the buildings of the 60s and 90s of the twentieth century.

The current state of the old city's buildings is often more than 100 years old, and therefore requires survey work and recommendations to overcome the functional and structural deficiencies identified during the survey. The specialists of Department of Construction and Civil Engineering of National University "Yuri Kondratyuk Poltava Polytechnic" carry out such works. One of such works was the study of the possibility of a new material for waterproofing a wall in a nineteenth-century building. In such cases, the use of traditional solutions is not appropriate. There is a need to use individual approaches based on the latest achievements in the production of building materials, structures, and technologies.

Individual approaches to solving professional problems in construction have become especially relevant in terms of the operation of existing housing stock, public and industrial buildings, because buildings built in the early twentieth century have been under the influence of external and internal factors, with the active influence of anthropogenic factors, i.e., those related to human activity, throughout their operation.

One of the most common problems in old buildings is excessive moisture in the ground part of the walls. To solve this problem, a group of specialists from the above-mentioned department investigated the effectiveness of using the injectable liquid "AQUAMAT-F" [13] to protect against moisture in the foundation part of the wall in a nineteenth-century building. To do this, the wall was perforated in the foundation part of the wall, and a waterproofing liquid was injected into the wall under minimal pressure through the resulting holes, which reduced the wall's moisture content by half. The absence of waterproofing in the wall used in the experiment is quite logical, since, as has already been proven by retrospective analysis, in the nineteenth and early twentieth centuries there were no reliable waterproofing materials, but at the beginning of the twenty-first century there is already a whole palette of waterproofing materials that have already become traditional, and new ones are emerging.

The method of hydrophobic injection is not effective for thick walls (over 1000 mm), for walls with a heterogeneous structure (voids) and for dense bricks. Under such conditions, the historical method of drying the foundations of the central building of National University "Yuri Kondratyuk Poltava Polytechnic" was restored, namely the method of installing external ventilation screens (tunnels). To install a ventilation screen that drains the underground part of the wall, a ditch has to be dug along the building, the bottom of which is 15 cm below the basement floor level. At the bottom of the ditch, a concrete foundation for the retaining wall is arranged. At a distance of 20 cm from the outer wall of the building, a retaining wall 30 cm thick is arranged. A channel 15 cm wide and 20 cm deep is punched in the masonry wall of the building. The channel starts 10 cm above the floor level. The channel needs to be insulated. Longitudinal section in Fig. 5, cross sections of the ventilation duct are shown in Fig. 6.

It is recommended to plaster the plinth to a height of 80 cm with a system of sanitizing plasters, for example, Ceresit WTA.

Works on the installation of the "sanitizing plaster system" shall be performed according to the following technology:

1) Prepare the substrate (remove old plaster, perform a depth of approximately 20 mm of masonry joints (which crumble and crumble) and antifungal treatment, primer the surface to strengthen the substrate and bind dust residues;

2) Apply a semi-finishing coat to the surface of the walls to increase the strength of the plaster bond with the substrate. The semi-spray should cover approximately 50% of the surface area of the substrate in the form of a grid, about 5 mm thick.

3) Apply a layer of plaster, leveling and grouting. After the plaster has hardened and dried (not earlier than 28 days), the finishing coating (facade silicate paint) can be applied.

4) Clean the area 2 m wide from the wall from bio-contamination, arrange a concrete blind area 1.2 m wide with a slope of 0.05%.

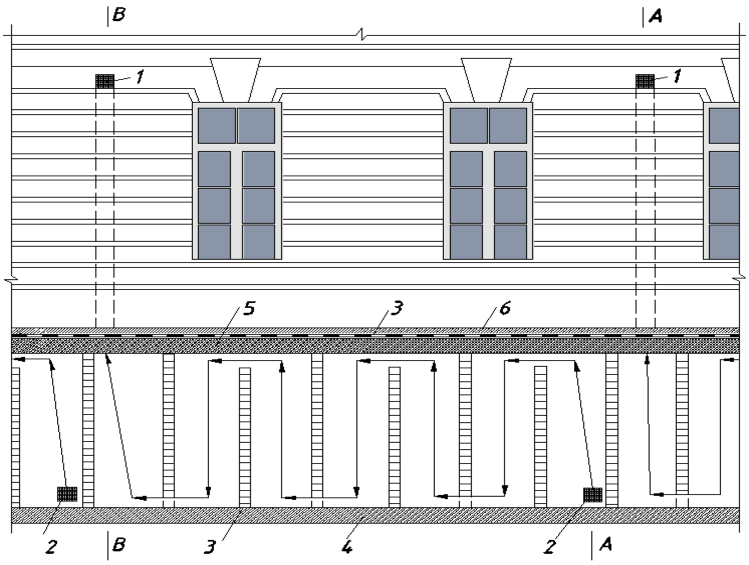

Figure 5 – Figure 6 - Longitudinal section of the ventilation duct

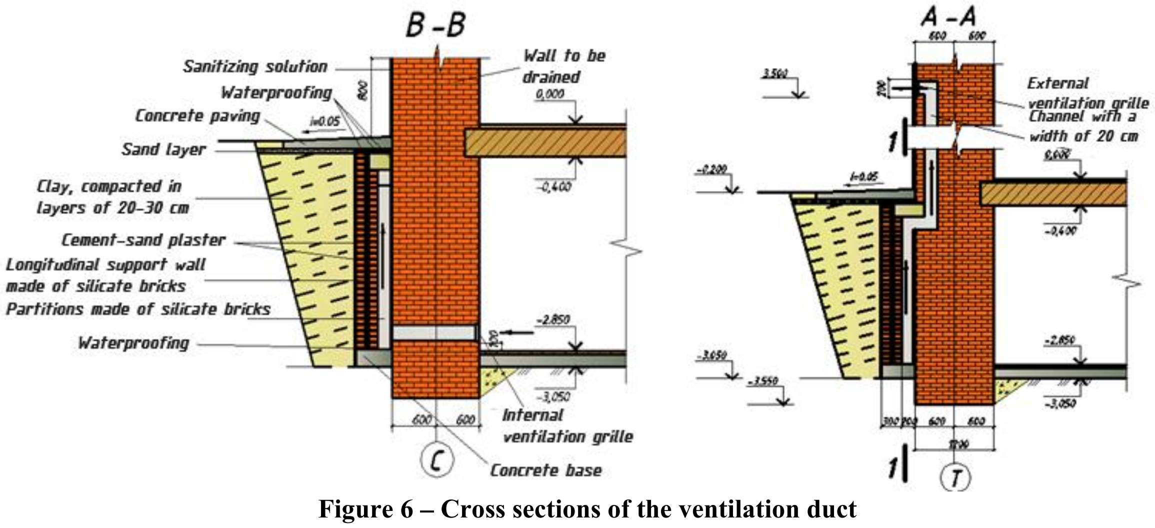

Figure 6 – Cross sections of the ventilation duct

Conclusions

As a result of a retrospective analysis of waterproofing structures at the foundation parts of walls, it was found that until 1953, there was no mandatory requirement for such waterproofing in domestic construction practice due to the lack of mass production of appropriate materials. Since 1956, with the transition of construction to an industrial basis, waterproofing of walls using mass-produced materials has been developed as a standard option. In modern conditions of construction production, covering such areas as restoration, it is necessary to use an individual approach to solve local problems of waterproofing the walls of buildings.

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References

1. Davison R.C. (1911). The Problem of Waterproofing. *Scientific American*, 104(11), 273-291 http://www.jstor.org/stable/26008410
2. Oliver A. (1997). *Dampness in Buildings*. 2nd ed. Blackwell Science, London
3. Rose W.B. (2005) *Water in buildings: An architect's guide to moisture and mold*. John Wiley@Sons, Hoboken
4. Schmidt H. (1999). Historische Bauwerksabdichtungen - Traditionelle und neuzeitliche Maßnahmen zum Schutz gegen Bodenfeuchtigkeit und zur Trockenlegung feuchter Wände. *Bautechnik*, 76, 581-598 https://doi.org/10.1002/bate.199903790
5. Michette M., Lorenz R., Ziegert C. (2017). Clay barriers for protecting historic buildings from ground moisture intrusion. *Heritage Science*, 5, 31 https://doi.org/10.1186/s40494-017-0144-3
6. Semko O., Filonenko O., Yurin O., Mahas N., Rudenko V. (2022). Moisture protection of structures adjacent to the ground in historic buildings. *ACADEMIC JOURNAL Industrial Machine Building, Civil Engineering*, 2(57), 53-58 https://doi.org/https://doi.org/10.26906/znp.2021.57.2585
7. Kubal M. (1999). *Construction Waterproofing Handbook*. McGraw-Hill, New York
8. Henshell J. (2000). *The Manual of Below-Grade Waterproofing Systems*. John Wiley, New York
9. Фадеев Н. (1930). Будівельне мистецтво: посібник для технікумів Держвидав
10. Попов Н.А. (ред.) (1950). Довідник архітектора: Том IX, перший напівтом: Будівельні матеріали. Видавництво Академії архітектури
11. Казачек Г.А. (ред.) (1955). Довідник майстра-будівельника. 2-ге вид., перераб. Державне видавництво
12. *Технические условия на производство и приёмку строительных работ. Раздел XII. Работы по устройству гидроизоляции.* (1953). Министерство жилищно-гражданского строительства Украинскй ССР, Киев
13. Filonenko O., Leshchenko M., Rozdabara O., Duka O., Pashchenko V., Filonenko D. (2019). Improving waterproofing properties in the wall basement area by injection method. *ACADEMIC JOURNAL Industrial Machine Building, Civil Engineering*, 2(53), 122-127 https://doi.org/https://doi.org/10.26906/znp.2019.53.1902

1. Davison R.C. (1911). The Problem of Waterproofing. *Scientific American*, 104(11), 273-291 http://www.jstor.org/stable/26008410
2. Oliver A. (1997). *Dampness in Buildings*. 2nd ed. Blackwell Science, London
3. Rose W.B. (2005) *Water in buildings: An architect's guide to moisture and mold*. John Wiley@Sons, Hoboken
4. Schmidt H. (1999). Historische Bauwerksabdichtungen - Traditionelle und neuzeitliche Maßnahmen zum Schutz gegen Bodenfeuchtigkeit und zur Trockenlegung feuchter Wände. *Bautechnik*, 76, 581-598 https://doi.org/10.1002/bate.199903790
5. Michette M., Lorenz R., Ziegert C. (2017). Clay barriers for protecting historic buildings from ground moisture intrusion. *Heritage Science*, 5, 31 https://doi.org/10.1186/s40494-017-0144-3
6. Semko O., Filonenko O., Yurin O., Mahas N., Rudenko V. (2022). Moisture protection of structures adjacent to the ground in historic buildings. *ACADEMIC JOURNAL Industrial Machine Building, Civil Engineering*, 2(57), 53-58 https://doi.org/https://doi.org/10.26906/znp.2021.57.2585
7. Kubal M. (1999). *Construction Waterproofing Handbook*. McGraw-Hill, New York
8. Henshell J. (2000). *The Manual of Below-Grade Waterproofing Systems*. John Wiley, New York
9. Fadeev N. (1930). *Construction art: a manual for technical schools.* Gosizdat
10. Popov N. A. (ed.). (1950). *Architect's handbook: Volume IX, first half-volume: Building materials*. Publishing House of the USSR Academy of Architecture
11. Kazacek G.A. (ed.). (1955). *Handbook of the master builder.* 2nd ed., rev. State Publishing House
12. *Technical Specifications for the Performance and Acceptance of Construction Works. Section XII. Works on the arrangement of waterproofing.* (1953). Ministry of Housing and Civil Construction of the Ukrainian SSR, Kiev
13. Filonenko O., Leshchenko M., Rozdabara O., Duka O., Pashchenko V., Filonenko D. (2019). Improving waterproofing properties in the wall basement area by injection method. *ACADEMIC JOURNAL Industrial Machine Building, Civil Engineering*, 2(53), 122-127 https://doi.org/https://doi.org/10.26906/znp.2019.53.1902