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WAYS OF REVITALIZATION WITH THE RESTORATION OF HISTORICAL INDUSTRIAL FACILITIES IN LARGE CITIES. THE EXPERIENCE OF UKRAINE AND POLAND

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Abstract

The theme of the revitalization of historical industrial areas in the central districts of large cities is international, taking into consideration the growing number of such examples in different countries. The main difficulty arises when an industrial object is an architectural monument and its authentic look should be preserved. Today, it is a common practice – the conversion of monuments of industrial architecture to the artistic territory of a new type – art clusters. The concept of an art cluster envisages that all the elements with an art orientation are interconnected, and the total effect of their combined action is several times higher than the outcome of single components. The first specific feature of an art cluster as a particular art unit, that it is not an accidental group of holders, who conduct particular kinds of artistic activities; it is the availability of tenants or owners who work for the common result, and their kinds of activities are correlated On the example of the Mystetskyi Arsenal in Kyiv – a historical fortress, subsequently redesigned as a defence plant, and the Na Woli Gas Plant in Warsaw, projects for the revitalization of industrial architecture monuments for multifunctional complexes are described.

Keywords*: Monuments of industrial architecture; Revitalization; Restoration; Art spaces*

Introduction

The intensive pace of industrial development in the countries of the Central Europe and the USA in the 19th century and the territories belonging to modern Ukraine in the second half of the 19th-20th centuries caused the concentration of industry in the areas of the extractive industry, and then the emergence of a specific type of settlement in the form of small cities and towns tied to mineral deposits and in the largest city-centres of the manufacturing industry. Subsequently, the railway connection, which took place mainly along the outskirts of large cities, further intensified the development of industrial areas.

Polish cities feature many unused post-industrial complexes, which are mostly dated to the nineteenth or the period around the end of the nineteenth and the start of the twentieth century. These complexes are often located on sites that are currently considered attractive and are close to city centres that enjoy dynamic development, which means that those complexes which were previously unused are now being restored and undergo adaptive reuse. This process

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also takes place in other European countries, and is associated with development pressure being exerted onto areas with favorable sites.

These processes have laid down the issues associated with industrial territories with capital manufacturing facilities that have lost their original functions and purpose, and most industrialized countries have faced similar problems today.

The topic of discussion among the public and experts was the question of the effective use of these territories with the maximum preservation of the appearance of individual structures and entire quarters of industrial development, which determine the face of the district, and changes in the directions of their functional use while solving the problems of urbanization of urban fabric and increasing the level of aestheticization. The problem of using industrial areas of the cities became especially critical in recent years when, in connection with the urban population increase, the need for additional territories for the development of residential buildings, service facilities and workplaces, had It is especially hard to solve the issue of reprofiling non-working industrial enterprises when the buildings are architectural monuments and entered in the monuments registry. That is why the authors studied not only sources on the revitalization of industrial areas but also publications devoted to the preservation of the historical environment, museumification [1-3] and modern restoration technologies that can be applied in the restoration of monuments of industrial architecture [4, 5].

In the publications of A. Dmytrenko and T. Kuzmenko, the current state of industrial areas of suburban settlements is reviewed (as a whole in Ukraine and in more detail – on the example of the suburban zone of the city of Poltava); the stages, prerequisites and directions of renovation are specified; it is given an example of the transformation technique and repurposing of the industrial area [6].

In recent years, the issue of the revitalization of industrial areas has often been associated with the creation of art clusters, art spaces of a new type, on their basis, arguing it, on the one hand, by changing the aesthetic needs of society, and on the other hand, by the fact that when re-profiling monuments of industrial architecture for art cluster it is easier to maintain its authentic appearance than when it is converted to a hotel, shopping mall or business centre. The publications of Rafael Boix, Francesco Capone, Lisa de Propris [7], Catarina Selada, Vilhena Inês da Cunha, Elisabete Tomás [8] are devoted to this topic.

From this point of view, *P. Kulikov et al.* [9], *M. Orlenko and O. Ivashko* [10], and *O. Ivashko* [11-13] made a significant contribution to the development of the art space functioning scheme based on revitalized architectural monuments. They proposed to consider the art cluster not as an architectural object but as a form of the functional organization of space, having distributed such open spaces to art objects, art centres and art clusters by the existing internal connections between them and the connectedness of the results of each participant.

Materials and Methods

The research involved scientific resources devoted to museumification, preservation of the cultural landscape, preservation of the historical territories of cities, revitalization of industrial enterprises, including for art clusters, sources interpreting the concept of the art cluster and the principles of its functioning, as well as project documentation on the technologies for the restoration of the architectural monuments. The methods of research applied during the research were as follows: the historical method, the comparative analysis, the graph-analytical method and the structural analysis based on the system approach.

The issue of the revitalization of industrial areas was highlighted in the publications of *T. Kuzmenko and A. Dmytrenko* [6], *P. Kulikov et al.* [9], *M. Orlenko and O. Ivashko* [10], *O. Ivashko* [11-13], *W. Dudek and J. Zawadska-Roman* [14], *M. Kracuski* [15], *M. Pszczółkowski* [16], *J. Alfrey and T. Putnam* [17], *M. Stratton* [18], *D. Kusnierz-Krupa* [19], *J. Jasieńko et al.* [20]. We also involved sources concerning new building materials and technologies. The significant contribution to this topic was made by *L. Luvidi et al.* [4], *D. Bajno et al*. [20], *A. Kheyroddin et al*. [21], *D. Garcia* [23], *A. Kwiecień* [24], *M. Masia et al.* [25]. The previous publications of the authors of the article [5, 9, 10, 19] were also devoted to this issue.

The study of *C. Selada et al.*[8] presented the concept of a creative cluster in urban space and analyzed its occurrence In particular, it was noted that creative clusters arise only in metropolises and large cities due to the inclination of the concept of creativity to the urban tendencies, however, they can become a factor of the revival of small and medium-sized cities in the USA, Great Britain and Canada.

Based on the surveys of the small towns of Obidos in Portugal and Barnsley in the UK, they proved that having a creative object by itself, produces convenience, since a place that attracts artists can attract people who love creative associations, so such objects often are complemented by public services – restaurants, cafes, shops, galleries. They proposed a methodology based on attracting and supporting creative infrastructures and on the theory of amenities for urban areas with low population density and rural settlements

Results and Discussions

Problems of the revitalization of historical industrial complexes

Buildings of the former "Na Woli" Gas Plant in Warsaw

Rehabilitation and restoration of historic industrial complexes, similar to the buildings of the former "Na Woli" Gas Plant in Warsaw, had in their attention history, field surveys, basic elements for restoration, etc. This prezervation problem will be presented on the example of the restoration of the former "Na Woli" Gas Plant complex (Fig. 1).

Fig. 1. View of the former "Na Woli" Gas Plant and Prądzyńskiego Street from the south-west, as seen in the 1920s. (Copy of a photograph in Archives of the Chair of the History of Architecture, Urban Planning and Contemporary Art of the Faculty of Architecture of the Cracow University of Technology)

This complex is located in western Warsaw, within the district of Wola. Historically, this area was located on the border between the villages of Wola and Czyste, and is currently outlined by Prądzyńskiego Street in the south, Kasprzaka Street in the north, Krzyżanowskiego Street in the east and Bema Street from the west. The Warsaw-Cracow railway line and the Warszawa Zachodnia train station are located close to the site (Fig. 2).

Fig.2. Orthophotomap of the "Na Woli" Gas Plant, as seen in the present. (Photo in Geoportal, https://mapy.geoportal.gov.pl/imap/Imgp_2.html?gpmap=gp0, 07.03.2020)

The construction of the Gas Plant was associated with the German Continental Gas Association from Dessau, which first built a Gas Plant in the Solec district in the middle of the nineteenth century and afterwards, due to growing demand, built another, this time in Wola. This location was probably associated with the close proximity of the previously mentioned Warsaw-Vienna railway line. This enabled the Gas Plant to have its own railway siding, which made it easier to supply it with coal [14].

The "Na Woli" Gas Plant complex developed over the course of two periods. The first is dated to between 1886 and 1900 and the second to between 1924 and 1939. The staged crystallisation of the complex caused it to have an ill-defined spatial layout. However, it should be noted that two compositional axes were delineated here: a north-south axis and an east-west axis. Both were highlighted by rows of trees in the past.

The buildings were built in the final quarter of the nineteenth century, in the historicising Rundbogenstil. They were designed to feature unplastered brick facades, characteristic of the industrial architecture of the period.

The buildings from the second stage of the complex's development, i.e. from the interwar period, are practically without detail and reference Modernism in terms of style. The distinct features of this architecture include plastered facades and the use of reinforced concrete prefabs [15].

The period of the Second World War saw significant damage done to the complex's substance. It was reopened in 1946 and was shut down in 1977. It should be noted that several elements of this nineteenth-century post-industrial complex have survived to the present, including the ammonia plant; the gas compressor station; the weighing building; the phenol plant; the furnace plant; the BTX plant; the apparatus and purifying stations; the gas tanks; the residential buildings and office buildings (Fig. 3). These structures have high cultural value, which was the reason behind placing the "Na Woli" Gas Plant in the Masovian Voivodeship Heritage Sites Registry in 2005, under item no. A – 482. The buildings of the historical complex in question are in varying technical condition. Some of them have already been restored and have undergone adaptive reuse, i.e. the building that housed the compressor and gas pumps currently houses the Gas Industry Museum, with an interactive exhibition and valuable archival materials concerning the history of the Polish gas industry and the "Na Woli" Gas Plant it. At present, the two gas tank buildings – former gasometres – pose a particular challenge to conservators. They are to be adapted into multi-functional facilities. A real estate developer plans to place exhibition halls, a concert hall, offices and apartments inside. It should also be added that the adaptive reuse of historical structures is the only way to save post-industrial buildings. If an adaptation project merits no opposition from conservators, it should be considered permissible, particularly as historical buildings often gain a new aesthetic quality because of such projects [13, 17-19].

Fig. 3. View of the former "Na Woli" Gas Plant—historical gas metre building, as seen today (Photo in Archives of the Chair of the History of Architecture, Urban Planning and Contemporary Art of the Faculty of Architecture of the Cracow University of Technology)

Concerning the restoration of the "Na Woli" Gas Plant and its former gasometer buildings specifically, it should be noted that the process of adapting such valuable structures must be performed in adherence to technical and conservation knowledge and in cooperation with conservation services. It should also be performed by an interdisciplinary team of specialists, i.e. by an architect who specialises in heritage conservation, a structural engineer, plumbing and electrical services engineers, a geologist and a wall conservation specialist. After performing architectural studies based on in-depth archival queries and on-site study of the building, one should investigate the condition of the building's structural system and perform a geological analysis of the soil. After preparing technical assessment reports concerning the structural system and the geotechnical properties of the soil, followed by applying for and receiving conservation guidelines as to the planned changes to the building's structure, one can proceed with preparing an architectural design of the adaptive reuse of the heritage site. Obtaining administrative permits associated with realising the project enables us to begin construction work. In the case of the gasometer buildings, the key matter is to reinforce the existing brick structure in adherence to the principles of technical knowledge and by principle of reinforcing the walls of historical buildings. This can be performed by using one of the following methods: using composite strip or surface applications (tape, mesh, carbon fibre-reinforced mats); polymer flexible joints (injections) or the use of helifix rods [20-25].

The brick walls of both the gasometers themselves and those of the complex's fence must be cleaned using mechanical and chemical methods. The mechanical method involves cleaning the wall with cold water, warm water or steam. Recently, hydrodynamic methods using special abrasives and nozzles that can regulate the cleaning stream and its pressure have entered use. One can also use a chemical method, i.e. use ammonium fluoride preparations and hydrofluoric acids (in the form of solutions or thixotropic paste). Historical walls should also be reinforced by means of a dedicated preparation that will prevent bricks crumbling, lower their absorptivity and porosity and increase their compressive strength. Proofing the facade against absorbing rainwater and damp from air humidity is also a priority and can be accomplished with hydrophobisation preparations, e.g. organosilicon compounds, silicon resins or silicon microemulsion compounds. Such wall structures often suffer from salinity. They can be desalinated using special desalinating pads. They force water and its salt content to migrate to the pad, wherein the water evaporates and the salt crystallises. Corroded bricks should be replaced, using materials that are compatible with the mortar and the bricks themselves. In this case, a premade mortar based on hydraulic binders, crushed brick, sand, special additives and colorants can be used. Trass is considered a good additive, as it changes the properties of the mortar when it is combined with lime, increasing its resistance to the formation of saltpetre rot and enhances its durability, elasticity, diffusivity and porosity.

The technological procedures listed above are only a small fragment of the entire spectrum of work that should be performed so that the former "Na Woli" Gas Plant and its gasometer buildings can be restored and adapted in adherence to the current state of the art in technology and engineering. One should only hope that the project, which started several years ago, will soon be completed and the historical gas plant complex will gain a new life because of it.

The "Mystetskyi Arsenal" in Kyiv on the practice of the Ukrrestavratsiia Corporation

In Ukraine, there are examples of transforming a former industrial facility - and at the same time historical fortification – into an artistic function – this is the former Old Arsenal in Kiev, now the Artistic Arsenal (Fig. 4). The uniqueness of the Mystetsky Arsenal complex in the historical district of Kiev – on Pechersk – lies in the fact that it has a rich history and changed its function several times – in 1712 there was a female Ascension Monastery, after its closure, the monastery was used as an artillery tseikhgauz, and since 1768 g. – as a cannon artillery yard for the repair and manufacture of guns. In 1797–1803 on the site of the Ascension Church, under the project of Lieutenant General I. Meller in the style of classicism with baroque elements and a layout of the hall type, the Old Arsenal of the Kyiv Pechersk Fortress was built in the north-western part of the Lavra Citadel, between the Kyiv and Vasylkiv gates.

In the Soviet times, the Old Arsenal complex was repurposed to meet the needs of a military campsite and rebuilt for the new function of a repair plant for defence needs. For this purpose, farmhouses, manufacturing workshops and a dormitory were built on the site of the excavated earthen ramparts, and a sports ground was equipped on the site of the excavated Novo-Kyiv ravelin. Since no one cared about saving the authentic appearance of the historical fortress, it led to the distortion of the forms of facades and rebuildings. Throughout its existence, the building of the Old Arsenal has undergone numerous reconstructions, destruction and annexes of various technical premises, not related to its stylistic decision.

Fig.4. The modern view of the Mystetskyi Arsenal from the Bell tower of the Kyiv Pechersk Lavra

At the initial stage, the specialists of the Ukrrestavratsiia Corporation conducted field surveys and scientific, historical and bibliographic works, a detailed engineering survey of the historical building, its communications and networks; performed stereophotogrammetric measurements of the facades, archaeological, geological and speleological studies of the site.

The superstructure of the Old Arsenal is based on the shallow foundations. The external and internal load-bearing walls have strip foundations made with the use of the rubble stone masonry and brickwork with the width of the foundation bottom of 2.12 – 2.80m. The foundation bottom was laid at the variable depth of 1.8 – 4.4m. The foundations for the internal brick columns are columnar made with the use of rubble stone and brick masonry, with a square footing in the plan, the sides of which are 2.56 – 3.5m, the depth of the footing are 1.6 – 4.4m. In general, the foundations under the building belong to different types, which under certain conditions could become one of the reasons for the uneven deformation of their base.

As a result of field surveys, it was found that the two-story brick building of the Old Arsenal, rectangular in plan, has an incomplete frame, axial size 165.900×133.450m, three runs of 8.800 m along the contour. The base was made of yellow Kyiv brick on a sand-lime mortar. It was recorded the surface destruction and increased humidity of the brickwork. The perimeter paving of the base had cracks and potholes in some areas, a reverse slope, and destruction. The height of the basement, in the contour of the house, is up to 3 meters and is determined by the depth of the foundations; the height of the basement in the courtyard at three levels reaches 4.8m. The relative height is as follows: the ground floor is 7.5m and the first floor is 5m.

The basement and the ground floor ceilings are brick cross vaults. In one section of the ceilings above the ground floor, the cross vaults were replaced by the bow-shaped brick vaults along the load-bearing metal beams; it determined the evenness of deformations. The emergency state of the cracked brick ceilings was determined: a lot of cracks and spots as a result of getting wet. It was recorded local destructions of the brickwork. The pillars (columns) of the cross vaults were made of the yellow Kyiv brick with the use of the lime-sand mortar.

Brick masonry of the walls is also made with the use of the yellow Kyiv brick on the lime-sand mortar. Intensive destruction and surface breakdown of the external and internal face sides of the masonry were observed. Over the entire surface of the supporting external walls, there were numerous cracks and spots characteristic of the wetting of masonry.

The crowning and intermediate cornices made of stone blocks were partially rebuilt during the restoration work. As a result of continuous wetting, freezing and melting of significant areas, the stone blocks of cornices were destroyed and crumbled. On the surface of the cornices, it was observed the biofouling in the form of trees and shrubs.

The colours of the facades and the character of the decor were also studied. The facades of the building are painted in ochre colour, some elements (keystones of arches, pilasters, cornice brackets, cornices, rustications, etc.) are plastered and painted white. All decor elements are built due to the relief of the brickwork.

When examining the building of the Old Arsenal, it was found that the primary reason for the deformation and destruction of building structures of the building is the subsidence of the soil foundation. It is proved that one of the constant factors that lead to a decrease in the strength of foundation soils and, as a consequence, to the deformation and destruction of the building structures, is the moistening of the soil stratum as a result of atmospheric precipitations infiltration, as well as water losses from utilities.

The idea of the project was to create a large museum town based on the Old Arsenal and the adjoining structures of the Kyiv Pechersk fortress, the museum complex connected with the museums of the Kyiv Pechersk Lavra and World War II. It made it possible to preserve and restore the existing Petrovskyi and Uspenskyi bastions, to restore the Old Arsenal with its conversion to the museum and exhibition function. To turn the former defence enterprise into a modern cultural and art institution of a new type, by the draft design it was envisaged to the re-create the authentic view of the historical fortress building and to improve the adjacent areas with earthen ramparts. According to the project suggestions, it was proposed to completely recreate the system of earthen fortifications, to clear the remaining ramparts from vegetation, to restore the powder magazine in the Uspenskyi Bastion, adapting it to the function of catering and the engineering function for the needs of the museum complex. The so-called Kyiv Gate between the Petrovskyi and Spaskyi Bastions was also subject to renewal and reconstruction. It was envisaged to provide it with the function of an underground entrance zone to the exhibition and information block with a conference hall for 1,200 seats, a lecture hall-atrium for 300 places, a cafe and an Internet cafe for 120 seats and two halls of temporary expositions. Since the Mystetskyi Arsenal was designed on a significant number of visitors, two-story underground parking for 420 cars was supposed to be under the ditch between the bastions. The result of large-scale restoration and reconstruction activities was to turn the site into a pedestrian zone.

The specific character of the layout of the Old Arsenal was the availability of the large open courtyard, which was not used. The project proposed to construct modern metal structures with a transparent coating in the courtyard and to arrange underground floors under the yard to accommodate technological premises and storage facilities, which would increase the exhibition space and provide year-round functioning of all rooms. The project also provided for additional museum and exhibition areas thanking the arrangement of galleries on the ground floor and mezzanines on the first floor.

Since the Mystetskyi Arsenal was to run as a multifunctional complex, it was also envisaged to perform an educational function. For this purpose, it was planned to arrange conference halls with the necessary equipment for lectures, art festivals, workshops and master classes.

Comprehensive restoration of the facades, taking into account the losses incurred, included the following kinds of works: the demolition of Soviet-times annexes; the washing or cleaning of the layers of paint with the use of a bead blasting apparatus; the removal of cement mortar stains; the dismantling of attic corner gables; the restoration and reconstruction of limestone stone blocks of the crowning cornice, door and window openings; injection works and restoration of brickwork according to the issued technology; a complete replacement of the roof and coating (the copper roof coating) and reproduction of the blind area.

Interior decoration was supposed to be made of the high-quality materials that comply with the modern sanitary and fire protection norms. Given the existing structural system of the house with brick cross vaults on the ground floor, which was created for the needs of storage facilities and which remains unchanged, it was provided for the premises for museum and exhibition halls of the highest grade. To accommodate engineering equipment, which occupies more than a third of museum rooms, it was necessary to create basements under the whole structure, except for the western wing with available old cellars. In a rigid vaulted structural system of the building, the most serious problem was to pass the ventilation ducts for the supply of fresh air into the room. In this case, the task was solved by passing through the spandrels. The vertical ventilation shafts pass in the four corners of the house where there are no vaults.

Given the fact that in the Soviet times, the plant workshops were located on these premises, it was surveyed for chemical and radiation analysis. The project provided for removing plaster from the walls and vaults, as well as asphalt concrete floor in each room. Brick walls and vaults were subject to comprehensive restoration and in some places remained in their original form.

One of the main problems concerned the complex hydrogeology of the area with the loess subsidental soil and landslide processes. The geological structure within the construction site is characterized by a complicated layering of soils of different genetic types and ages, including the loess subsidental soil. The ground conditions of the site belong to the first type by subsidence. Besides, the additional problems were created by the availability of basement unit's only under one part of the building, and the fact that one part of the building was damaged by a powerful explosion during the Second World War. The groundwater was found at depths of 7.1–10.0m during the survey period. There was a probability of rising of the predicted groundwater level for the estimated period by 2.0m compared with the level recorded during the survey.

Since the average load values at the base level of existing foundations after the reconstruction of the building should have exceeded the designed soil resistance and the initial subsidence pressure, one of the components of the reconstruction of the Mystetskyi Arsenal complex was the strengthening of authentic foundations, ensuring the operational reliability of the building and excluding the possibility of any deformation of the building structures (Figs. 5-7).

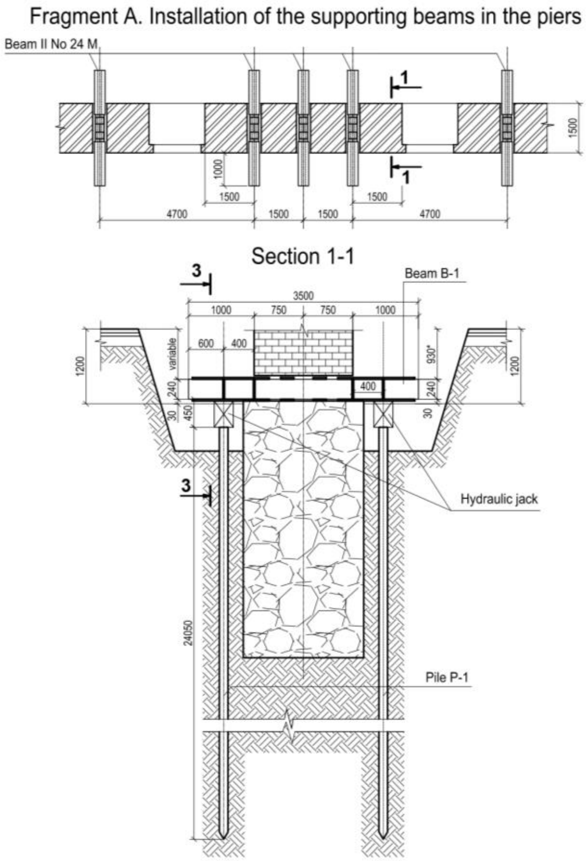

Fig. 5 The scheme of reinforcing the external walls of the Mystetskyi Arsenal with supporting beams and jacked piles

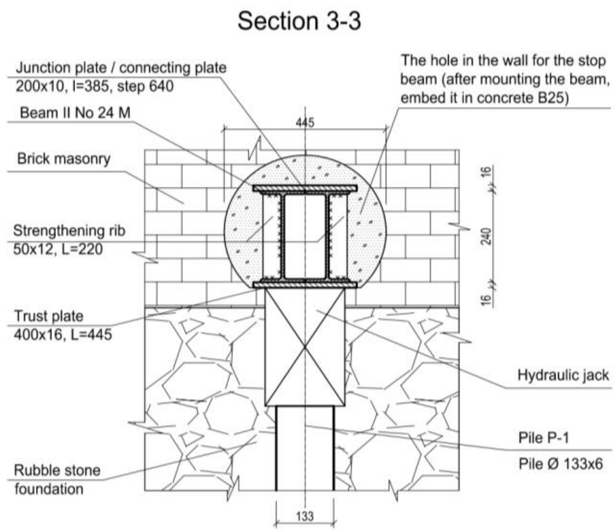

Fig. 6. The scheme of reinforcing the external walls of the Mystetskyi Arsenal with supporting beams and jacked piles

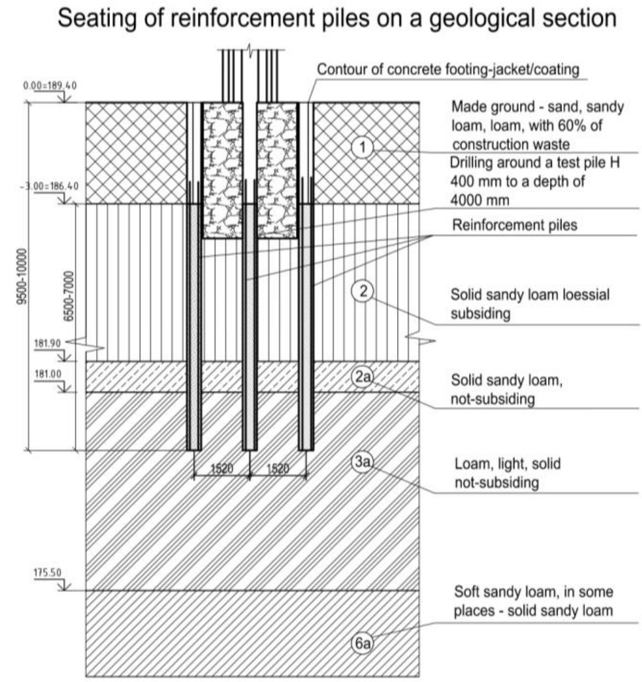

Fig. 7. Strengthening the foundations of the columns of the Mystetskyi Arsenal with piles. Seating on a geological section and a graph of the subsidence of piles under the pressed loads

The best option for reinforcing the foundations of the exterior walls of the building was to transfer the partial load from the walls with the help of cross-bearing beam passing through the walls and leaning on jacked piles Ø = 133mm, that is, in the form of a U-shaped frame with rigidly clamped jacked piles. The similar structural and technological solution was expedient to use to strengthen the columnar foundations under the brick pillars of the building and the foundations of the walls in areas with the basement, as well as sections of the walls that will serve as a support for the courtyard ceiling.

When performing the works on the reinforcement with piles for the external and internal walls and columns, their inclusion in the work should be performed at the same time, that is, it is forbidden to include only piles for the external walls separately from the internal walls and pillars.

Description of the technology of piles pressing for strengthening the external and internal walls of the building

1. In order to cut holes Ø400 mm in the brick masonry of the building walls above the rubble stone layer of the foundations and to cut holes in all directions it is forbidden to cut the neighboring holes simultaneously, to insert steel reinforcement bars in the holes in the wall and to cement them with B25 concrete. After the concrete has hardened in the holes (7 days), it is allowed to make intermediate holes on the next step.

2. The insertion of piles is carried out with the use of two jacks, simultaneously located at the ends of the beam. Piles are placed as close to the rubble stone masonry as possible.

3. The piles' insertion procedure: install the first section of the pile (with a pointed end) under the jack for inserting, and using a hydraulic jack, insert the section so that the next section can be welded to the lower section. Next, repeat the inserting process to a load of 50t/s. When the inserting indicators have reached the design parameters, let the piles stand for at least 1 day

and repeat the inserting. If the load is stable, stop the insertion.

4. The reinforcement of the piles is carried out by a reinforcing cage with an average bearing rod Ø 25 AIII, which is installed in the pipe cavity in sections that are welded together by patch rods.

5. Grouting of reinforced piles is performed by concrete M300 on fine aggregates (fraction of not more than 5 - 10mm) using a concrete pump in the direction from bottom to top. It is taken concrete with the water permeability grade W4. Concrete compaction is carried out by a vibrator mounted on a metal reinforcing frame. After the concrete has hardened (7 days at least), the piles are wedged.

The work began on reinforcing the foundations 82 with jacked piles, which ensured the transfer of load to more durable layers of soil at a depth of 10–15m and resisted deformations and "splitting" of the building into parts (as happened in the "House with Chimeras", where two parts of the building were put on various foundation systems – strip and piled) (Fig. 8).

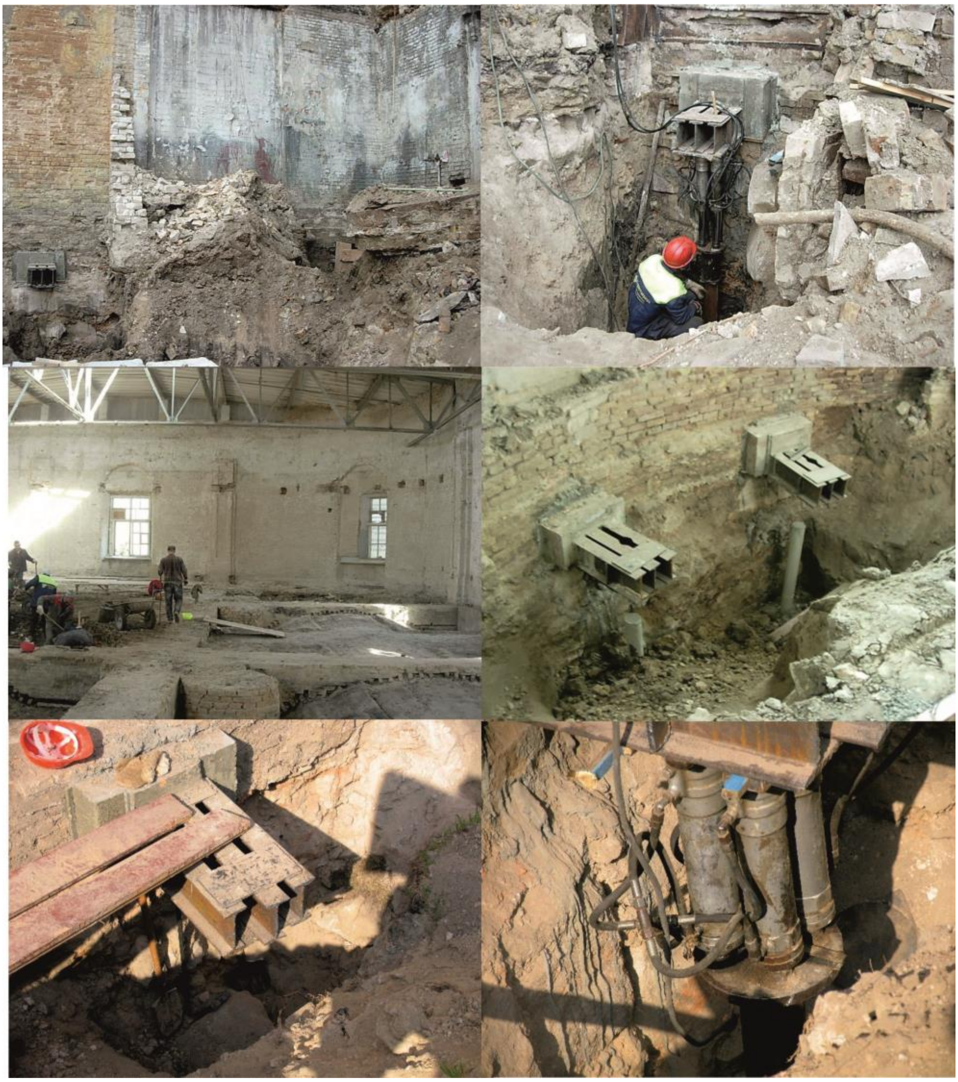

Fig. 8. The process of strengthening the foundations of the columns of the Mystetskyi Arsenal with piles

Given the large areas for engineering equipment, basements up to 3 – 4.8 metres high were created under the building in those places where there were no. Vertical ventilation shafts were located in the four corners of the house, where there were no vaults. The interior design provided for the replacement of plaster on walls and vaults and asphalt floors, as well as a comprehensive restoration of brick walls and vaults. It was recommended to strengthen and restore the walls and floors.

One of the most successful wall reinforcement methods used at Mystetskyi Arsenal was the method of reinforcing brickwork with cementation (Italian method "cemented mesh", "Raticolo cementato", first used by Fernando Lizzie in Italy), which was carried out to increase strength and strength structures, counteracting tensile forces by inserting steel reinforcement into the wall through the drilled holes that are filled with the solution. This increases the allowable efforts for masonry, restores the structural integrity of the masonry. Steel rod fittings are firmly connected to the masonry in which they are cemented. The volumetric integrity of the reinforcement mesh is provided by the fact that the reinforcement of the masonry overlaps each other. The more the wall is damaged, the easier it is to reinforce it by this method [26, 27].

Description of the applied brickwork restoration technology

1. The relaying of the disassembled sections of the masonry walls of the eaves and the protruding parts of the frieze of the building is done with brick M100, Mp3 35 wit the use of cement-lime mortar M75 (table 1).

Table 1. The composition of the cement-lime mortar M75

Slurry formulation	Part by volume
Portland cement M 400	1
Lime paste of class B	0.5
Stream sand	5.5

2. To pull down those masonry fragments that are deformed and untied with the main walls, as well as those that have deep destruction of the brick and masonry mortar as a result of mechanical stress and wetting (the socle part). Perform their relaying and additions with new brick M 100, Mp3 35 with the use of mortar M50, presented in Table 2.

Table 2. Slurry formulation M50

Slurry formulation	Part by volume
Portland cement M 400	1.0
Lime paste of class B	0.7
Stream sand fraction	6.0
Water	4.0

To connect the places of additions with the surfaces of the old brick, moisten the old brick with water, and then apply the priming coat of Acryl 60 water solution (1 volume part of Acryl 60 + 4 volume parts of water). Add Acryl 60 (1 part of Acryl 60 + 4 parts of water by volume) into the masonry mortar.

"Acryl 60" is an adhesive and plasticizing additive, which has the consistency of a milky liquid.

The crack injection process in a brick masonry wall

The technological scheme of the crack injection process:

a) preparatory phase:

– marking of injection tube installation place;

– surface coating of cracks with mortar to a depth of 1 – 2cm;

– drilling ports with a crack opening width of less than 20mm;
– the injection of pipes into the ports on a gypsum mortar;
– washing cracks and wetting masonry;
b) the main stage:
– preparation of the grout;
– injecting (injection of grout)
c) the final stage:
– extraction of injection pipes;
– clearing masonry from gypsum mortar;
– closing up with putty of the left recesses.

The injection strengthening technology

In the masonry in which the injection reinforcement is to be carried out, the places of natural and artificial (drilled) holes are affected and marked for the further installation of injection pipes.

1. If open cracks are relatively far apart and probably not connected (50 cm or more), the holes are located in the cracks with such a distance from each other, presented in Table 3.

Table 3. Dependence of the distance between holes on the magnitude of crack opening

Magnitude of crack opening, (mm)	Distance between holes, (m)
More than 10	1.0-1.5
5-10	0.5-1.0
5	0.3-0.5

2. If there is a network of branched cracks, natural and artificial (drilling) holes for injection pipes are staggered with the maximum possible use of natural holes, that is, the cracks themselves. The average distance between the holes is 0.3 – 0.5m, while the exact observance of the checkerboard order is not required.

3. Drilling of holes is carried out if there are hidden or small cracks in the masonry, where installation of injection pipes without drilling is impossible. In open cracks, punching of holes with a jumper to a depth of 5 –10cm is allowed. Holes are drilled in the joints of the masonry along the direction of the seam.

4. To prevent leakage of the grout from the open cracks, the latter on both sides of the wall are applied to a depth of 1 – 2cm with a grout of the following composition (parts by volume) presented in Table 4.

Table 4. The composition of the mortar for walls on both sides

Slurry formulation	Part by volume
Lime paste	2.0
Cement grey M 400	0.5
Sand	5.0

On the surface of the masonry opposite from the injection site, control holes remain at a distance of 0.5 – 1.0m from each other.

5. The injection pipes are mounted on gypsum mortar into drilled holes directly into cracks to a depth of 5 – 7cm. At the same time, as a rule, 5 – 7 pipes are used.

6. The washing of cracks and moistening of the masonry is carried out with water using an injection pump immediately before injection. The average water consumption for each hole is 3 – 5 litres.

Cracks in the masonry are injected with a grout of the following composition presented in Table 5.

Table 5. The composition of the grout for injection of cracks in the masonry

Slurry formulation	Parts by volume	Kg per 1,000 l of mortar
Lime paste (not lower than class B)	1	466.7
Portland cement M 400	1	400
Sand	1	400
Superplasticizer C-3		6
Akryl 60		47
Water		433.3

The composition of the mortar and the required water content in it are specified after the test injection. The thinnest cracks (up to 1 cm wide) are injected with a 1: 1 lime-cement mortar without filler.

The process of preparing an injection grout consists of dosing in parts of its components by volume and mixing them mechanically or manually.

The procedure of loading the components in the mixing tank should be water-lime-cement-filler. The injection grout should have the consistency of "liquid sour cream" – for narrow cracks (opening up to 5 mm) and "thick sour cream" – for wide (opening more than 10mm).

The ready-mixed mortar is passed through a sieve with a cell of 1.5-2.0mm. The amount of solution for injection should correspond to the time of its viability (about 3 hours).

Injection operations

a) The injection works must be carried out at an average daily air temperature of at least + 5°C;

b) The injection works in winter can only be carried out on internal walls if the building is heated;

c) The injection of walls with a thickness fewer than 1.5m can be carried out on one side of the wall;

g) The injection of any masonry area starts from the bottom row of the holes. The initial overpressure during injection should not exceed 0.5 – 0.8kg/cm^2. The injection of the grout into each hole is carried out continuously, with a moderate flow rate of the grout. The neighbouring and located above the pipe when a solution appears in them, they are temporarily drowned out by wooden corks. The final discharge pressure is 5 – 8kgf/cm^2.

The hole filling is considered complete if a column of thick solution appears in the holes (cracks), or this solution is supplied to them under a pressure of 5 – 8kgf/cm^2.

The injection pipe into which the injection was carried out, as well as the plugged pipes, can be removed immediately after the completion of the injection of the solution into the hole. Places of breakthrough of the mortar from the masonry array are temporarily covered with gypsum mortar. The injection of the grout during the hardening of gypsum (5 –10 minutes) stops.

The second injection is carried out the next day into the holes with the highest consumption of injection grout.

1. The injection pipes must be removed from the holes at the end of injection and control injection.
2. The surface of the masonry at the end of the work is cleared from the gypsum mortar mechanically.
3. The recesses from the pipes are coated with a grout.

4. The smudges of the injection grout on the surface of the masonry should either be immediately washed off with a stream of water or carefully cleaned mechanically (scrapers, pitching chisels) after the grout has dried.

Antiseptic processing of fragments with biological damage

Fragments of masonry walls with white spots of wetting and efflorescence out and visible signs of biological damage (fungi, algae) are subject to antiseptic treatment. It is mostly eaves, adjoining to walls of entrance canopies, walls of a socle under the siding. Antifungal treatment of masonry and plaster is carried out by septic preparations of Ukrainian or foreign production.

For antiseptic processing of walls, the use of Ukrainian drugs with a wide spectrum of action "Ambizol IC", "Carbocide", "Fitosaid" or similar foreign ones is proposed. Ambizol IC is a mixture of dithiocarbamic acid derivatives of sodium oxide and urotropine in water. Material designed to protect from mould fungi. For processing, a 1 – 5% solution of the drug in (parts by volume) is used, the flow rate of the solution is 500mL per 1m^2. From the foreign drugs we offer materials:

– ADOLIT Bohr flussig – of the firm "REMMERS" (Germany) – concentrate, diluted with water in a ratio of 1: 9;

– MIPA – manufactured by Sadolin (Estonia), this drug is mildew preventer, it can be added to paints.

Anti-efflorescence processing of masonry and plaster of walls with the efflorescence

Anti-efflorescence processing is carried out in the case of the salt efflorescence on the surface of the masonry or plaster and is designed to be kept in the thickness of the wall and plaster by converting water-soluble salts into insoluble salts with sediment in the pores of stone and plaster. For the anti-efflorescence processing, it is recommended to apply fluid Olafir, Kaparol.

The anti-efflorescence processing technology

The anti-efflorescence processing is carried out in two stages with intermediate drying and removal of salts from the processed surface.

1. Remove the salt from the surface mechanically with spatulas, hair and metal brushes.

2. To begin the first anti efflorescence processing with a hairbrush or paintbrush with a solution of Olafir concentrate in water: 1 part of the concentrate + 4 parts of water by volume. The technological break is 1 day to dry the base.

3. The second anti efflorescence processing with Olafir solution in water: 1 part of the concentrate + 2 parts of water by volume. The technological break is 1 day and immediately rinses the surface with water.

4. To apply plaster (or painting on plaster).

The specialists of the Ukrestavrtsiia Corporation carried out a comprehensive restoration of the facades of the Old Arsenal and its interiors with the removal of late layers.

Conclusions

The primary reasons requiring comprehensive activities for the revitalization and use of the areas of unprofitable industrial enterprises are as follows: the shortage of land for the new development in the central part of the city and, at the same time, the location of industrial facilities in its centre; the increase of the cost of rent and use of land that leads to the provision of incentives for their more effective use; the increased demand for commercial real estate; limited financial resources for participants of the construction market. The experience gained in

Ukraine and Poland testifies to the possibility of successful repurposing of the monuments of industrial architecture with preservation of their authentic appearance and, if necessary, interiors.

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