

Approach to conservation of irregular stone masonry based on archaeological excavations in the Black Sea basin

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Abstract. The article presents and describes the methodology of conservation of masonry structures that are architectural monuments discovered as part of the work carried out during archaeological excavations. The authors' experiences presented in the article result from many years of cooperation between the Faculty of Civil Engineering at Warsaw University of Technology, the National Museum in Warsaw and the Antiquity of Southeastern Europe Research Center at the University of Warsaw. Examples of preserved masonry structures come from excavations located in the Black Sea area - from the archaeological site in Tyritake in Kerch on the Crimean Peninsula and Tanais near Rostov-on-Don in Russia. Works on masonry structures located in the area of archaeological excavations are characterized by a unique specificity covering both formal issues, resulting from international standards and agreements regulating the conservation of historic buildings, as well as technical and environmental issues. The basic technical issues include ensuring the safety of further excavation works, protection of masonry structures against the destructive effects of atmospheric conditions and preparing the structure for possible exhibition in archaeological parks organized on the site of excavations. Environmental issues relate to local, social and economic conditions. The article presents the procedures that should be used in the conservation of these types of structures and presents the specific technological and material solutions used in the presented objects.

1 Introduction

The European Convention on the Protection of the Archaeological Heritage [1], drawn up in 1992, recalls that the archaeological heritage is a fundamental importance to the knowledge of the history of the mankind. Its protection as well as reliable research are the obligations of all who are responsible for the scientific truth. People living nowadays have this duty to fulfil for future generations. This is closely related to the wider aspect of social, economic and educational issues resulting from the universally recognized principles of sustainable development. The last decades have confirmed that the European archaeological

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heritage, which is evidence of the oldest history and often extinct civilizations, is in seriously jeopardy of destruction. According to the convention, the subject of the archaeological heritage are all of the remains, objects and any other traces of humanity from past eras, whose maintenance and analysis will help to trace the history of mankind and its relation to the natural environment. These are also objects for which excavations and discoveries or other methods of researching the history of mankind and its environment are the basic source of information. Among the most important traces of the ancient epochs and civilizations are architectural and structural monuments that are evidence to the technological development of their authors, the standard of living of residents and the aesthetic canons that were in force in past eras. The archaeological heritage includes structures or groups of them, as well as their surroundings and urban layouts. Due to the continuity of the building arts, knowledge about civil engineering, architectural and structural systems, forms, technologies and material and technical solutions can also be of great importance to the present day. Under the Convention, its signatories were obliged to establish a legal system to protect the archaeological heritage, and in particular to create archaeological reserves - parks where exhibitions of architecture and construction saved for future generations should be exhibited, even if only slight traces remain. They will also be left to future generations as a source of analysis. To preserve the archaeological heritage, being part of the cultural heritage, as well as the reliability of research into objects and their areas, the Convention requires the following principles: ensuring adequate control and supervision of archaeological and conservation excavations; application of non-destructive testing methods that do not spoil historical originality (this is particularly important for use in conservation, security, reinforcement, and durability of building structures); adequate protection after examination of all discovered artefacts (in extreme cases where this is not possible due to various reasons, it is recommended to backfill them to allow testing in the future); proper conservation of all archaeological objects, especially architecture and construction, which most often remain in a state of permanent ruin and are exposed to various destructive effects. It should be noted that the best solution for all archaeological monuments, and especially for architectural-structural objects, is their proper maintenance and leaving them on their sites. The "in situ" exhibition, with the appropriate area, historical and geographical context, shows the full truth about the historic building and is a much more complete form of education and promotion of monuments. All of these recommendations imply the necessity of many interdisciplinary activities, including engineering ones, which include proper analysis, and often also necessary changes, spatial development plans for areas on which archaeological historical and architectural objects of architecture and construction can be found, as well as improvement and implementation of the proper methodology in conservation, structural and engineering works and technical works at these monuments.

In the article, the authors present the principles that should be followed by conservators dealing with irregular masonry in the area of archaeological excavations. This methodology is the result of experience and conclusions from the authors' conservation works carried out at archaeological sites located in the Black Sea area. The research was carried out as part of conservation missions by the Division of Fundamental of Building and Sustainable Development of the Civil Engineering Faculty of the Warsaw University of Technology in cooperation with the National Museum in Warsaw (Conservation Mission in Tyritake in the Crimea in Ukraine in 2011–2013) and the Institute of Archaeology of the University of Warsaw and the Antiquity in South-eastern Europe Research Centre (Conservation Mission in Tanais near Rostov-on-Don in Russia since 2016). The building structures preserved as part of the research were, in both cases, relics of urban buildings from the period of the Bosphorus of Kimmer, from the 5th century BC to 5th century AC [2]. Their structures, in terms of technology and material, are similar in Tyritake and Tanais.

2 The state of preservation of ancient architectural objects

One of the greatest difficulties related to the protection and conservation of ancient architectural objects is the poor technical condition in which they have survived to modern times. This results directly from the time that has elapsed since their creation and use until today. For about 20 centuries that divide us from antiquity, these structures have been subjected to environmental conditions, such as rains, low temperatures, earthquakes and floods, as well as human activities, which could have both a positive (repairs, adaptations) and destructive (demolition or warfare) impact on maintaining the technical condition. An important feature that makes part of the structures last for a long period of time in good technical condition is the durability of materials, elements, and structural systems. The durability of structures depends on many factors, such as: the types and quality of materials from which they were made, adopted construction technologies and technical solutions, structural systems, expositions in field, qualifications of builders and the resulting quality of construction works, resistance to environmental changes occurring over the course of history (for example raising or lowering groundwater level, climate changes), resistance to changes in civilization (for example creation of motorways in the immediate vicinity of monuments, causing vibrations).

Due to the technical condition, antique architectural monuments can be divided into four groups [3]:

- monuments that do not require (or require very limited) conservation intervention,
- monuments with a preserved structure that do not meet the modern construction safety and usage requirements,
- monuments in the form of ruins,
- monuments that have not survived to this day.

The discoveries of architectural monuments belonging to the first two groups are relatively rare and exceptionally valuable. The most frequently discovered relics on archaeological sites belong to the third group. The necessity of their conservation results from the assumed method of their later exposure. One of the most common methods is the exhibition as a part of archaeological parks in the open air. This type of exposure is associated with a number of factors destructive to the monuments.

3 Methodology of conservation of ancient masonry structures at archaeological excavations

3.1 Characteristics of irregular masonry

One of the common types of ancient masonry structures exposed as part of archaeological excavations are irregular masonries. In the case of sites where the research was carried out, they were made of ashlar and stones from various limestone rocks, shaped or broken, mostly unsorted, of different structure, degree of sedimentation, porosity and absorbability, and, what is associated with it, humidity. Some types of rocks from which masonry elements were made have also shown granular disintegration. A clay mortar based on clay and sand found in the surrounding soil was used as the binder. In irregular masonry strength is directly related to mortar adhesion and internal cohesion [4]. Due to observed lack of mortar adhesion, the analysed walls had low strength and as a result - low durability. The structure of the walls is degraded to a large extent, which in addition to possible conscious human impact, results from centuries-long environmental processes, including long-term moisture and biological aggression in the ground and destruction caused by exposure to rainwater. After being exposed in the excavation, structures are subjected to the action of variables and sub-zero temperatures, especially to the repeated processes of

freezing and thawing of water inside the structure. Water penetrates inside the wall, moistens the masonry elements and mortar, causing them to swell and weaken. The damp walls are more susceptible to deformation, they lose their original strength and load-bearing capacity, by weakening of the physical properties of the materials they create. The binder, fine sand, and even poorly bonded small wall elements are washed out from the mortar by water and the waste is rinsed off the rock (ablation). In the tested irregular walls, made on a clay mortar, washouts is a particularly destructive phenomenon.

The specificity of the irregular masonries, their structural and physical properties make their conservation a complex and difficult process. In the case of structures located in Tanais in Russia, the additional problem was biological destruction, caused by the damaging effects of green plants, lichens and weeds growing in spring in the excavation. Environmental impacts in both Russia and Ukraine are characterized by high temperatures in the summer, with strong solar radiation and low temperatures in winter, with snowfall and negative temperatures causing freezing of water. There is also heavy rainfall in autumn and spring. These are the impacts that further complicate the conservation works and cause the destruction of the wild walls. The basic problems that need to be solved during conservation works are: reduction of absorption of water, increasing internal cohesion, related to the need to consolidate the internal wall structure, restoration and protection of damaged parts of walls, and reprofiling with removal of destructive plant interactions.

3.2 Maintenance works' program and assumptions

In order to carry out the proper conservation works, the following conservation assumptions were adopted [5, 6]:

- Works conducted on stone structures have to be comprehensive and based on reliable researches with caution and due to the rule of conservation and construction interference minimization as a preservation of natural and original nature of monuments.
- Different kinds of stone structures' comprehensive conservation should include their exceptional nature, historical, educational and aesthetic value. Monuments have to be prepared to public exposition in a permanent ruin state in its natural environment. All conservation and restoration works have to consider future ancient architectural monument exposition as an archaeological park. All eventual substructures and complements should be recognizable and easily distinguished from original structures.
- Due to the impossibility of total elimination of destructive environmental influence to masonry located in the excavation (season rains, moisture, low temperatures, the frosting and defrosting process of water in masonry structures and units, weathering processes), it should be minimized and the most damaged and endangered structures should be consolidated.
- In order to reduce excavation slope destruction (full elimination is impossible due to open excavation assumption) the proper protection, for example with net anchored to bottom and top parts of a slope is considered. The proper profiling of the excavation's surrounding surface is required with an effect of reducing or eliminating the inclination in the direction of the excavation. Moreover, the drainage system should be provided around the excavation to reduce rainwater inflow.
- It is absolutely necessary to eliminate or limit the biological destruction of excavations and masonry structures by permanent removal of plants, lichens and weeds.
- All reprofiling activities of the walls should be made after previous detailed survey of the original wall structure. Reprofiling of the wall and reconstruction of its part in order to strengthen the walls or show the architectural and construction context can take place only through anastylosis, or when it is completely impossible through semi-anastylosis (the use of wall elements, which we are sure that formed a wall, although we are not sure

where exactly they originally were), preserving the original way of binding and arranging wall elements.

- In order to eliminate or reduce destruction of masonry units and structures, the proper hydrophobization treatment with appropriately selected materials should be provided (alkylalkoxysiloxanes with additions). Due to the qualitative and structural difference of masonry elements, stones with various degrees of porosity, permeability, absorbability and hardness should be found in the excavation, and then different hydrophobic agents should be used. It is important that the hydrophobization agent should not limit the diffusion of gases. The appropriately protected part should then be exposed to the destructive effects of atmospheric factors, so that after a year they can be tested and their condition can be checked. It should be remembered that hydrophobization is not a permanent procedure due to the limited durability of the agents and after application, to achieve its effectiveness, it must be periodically repeated systematically.
- Works undertaken for the first time in a given area, have to be considered as trial works, of which results should be examined in the following years and used as a base to further improvement of applied treatment. Therefore, such works should not be carried out in a wide range and should not relate to the most important monuments from a given area.
- Conservation materials should be selected based on the conservation knowledge, rules and experience and in compliance with the principles of compatibility of materials but, moreover, it should include social aspects (for example possibility of theft or devastation), economical aspects and availability.

3.3 Stages of conservation works

On the basis of the conservation works, it is possible to specify the actions necessary to take to effectively protect and carry out conservation of historic structures made in the technology of wild walls. These include the following conservation activities [5, 6]:

- Macroscopic and laboratory examinations aimed at identification of the technique of rising masonry, including identification of masonry elements, bonding and their arrangement in the masonry, and physical properties of mortar and masonry elements.
- Detailed geometrical survey of masonries, with their location in the plan, preparation of geometrical survey, drawing and photographic documentation. A specific form of measurement and preparation of drawing and photographic documentation is the digitalization of the excavation area (masonry structures) using 3D laser scanning [6, 7].
- Preparation of the appropriate mortar.
- The reprofiling of existing masonry parts with the anastylosis or semianastylosis method, using prepared mortar; internal bonding of the wall, and internal consolidation. During reprofiling, all plants destroying the masonry structure should be effectively removed (if chemical agents are used, their impact on mortar and masonry elements should be checked beforehand). The internal integration of masonry structures can be carried out using the injection method, introducing the injection in the form of grout and consolidation - repair of welds. The masonry reprofiling was realized in stages:
 1. rebuilding, bonding, consolidation with appropriate mortar,
 2. pointing – placing a pointing mortar to a fresh grout ,
 3. joints complementation with pointing mortar after grout hardened,
 4. mechanical cleaning
- hydrophobization treatment,
- additional excavation slope protection.

For properly made reprofiling, in connection with possible superstructure (partial reconstruction) of the wall, the previously made documentation is necessary (photographic, drawing, numerical). The collected data will present the original arrangement of elements in the wall. It should be ensured that the binding method and arrangement of the wall elements in the reprofiled wall reflects the original layout, preserving historical truth. The superstructured (reconstructed) layers should be visibly separated from the original ones (for example by placing a ceramic layer in the joint).

4 Application of methodology

4.1 Archaeological site of Tyritake in Kerch, Crimea

The Maintenance Mission of Civil Engineering Faculty of Warsaw University of Technology had been a part of the Polish Archaeological Mission “Tyritake” [5, 6], held by the National Museum in Warsaw, between 2011 and 2013. Archaeological and maintenance campaigns were performed under “The Bosporan City Tyritake” project, which was compounded of not only archaeological research but also comprehensive geological, urban, paleozoological and paleobotanical analysis of ancient city territory. The aim of the project was to form a complete image of living conditions in this antique settlement. The objects of research and maintenance works were ancient masonry structures located in excavation no 27 (Fig. 1) in Tyritake archaeological site in the city of Kerch (Ukraine).



Fig. 1. Excavation no 27 in Tyritake archaeological site in the city of Kerch (Ukraine).

During three seasons of Maintenance Mission, it was possible to perform all phases of the conservation project. At first a preliminary research was done, including determination of renovation mortar, which took into account not only mechanical and durability characteristics but also important economic and social aspects. Moreover, an influence of various hydrophilization treatments on masonry units was investigated (Fig. 2).



Fig. 2. Example samples for determination of influence on masonry units and environmental durability of hydrophobization treatment.

Conservation works carried on the masonry located in the excavation was focused on consolidation of existing structures with partial, limited, reconstruction by anastylosis or semi-anastylosis. Due to the originally used clay mortar, for the renovation a clay mortar stabilized with cement with lime was used. For the finishing of the joints, a pure clay mortar was applied. The example of result of conservation work is shown in the Fig. 3.



Fig. 3. Defence wall in the Tyrıtake archaeological site before (left) and after (right) conservation.

4.2 Archaeological site of Tanais near Rostov-on-Don, Russia

The ancient city of Tanais was formerly located probably at the shore of Azov Sea. Nowadays, due to geological changes of the area, it is located at the mouth of the Don River. Archaeological works at this site have been carried out there since 1995 by two institutions of the University of Warsaw – the former Archaeological Research Centre of Novae (presently the Antiquity of Southern Eastern Europe Research Centre) and the Institute of Archaeology. The city of Tanais was founded at the beginning of the 3rd century BC by Greek settlers and existed until the middle of the 3rd century AD, when it was probably destroyed by Sarmatian tribes. In the second half of the 4th century and in the first half of the 5th century, the remains of Tanais were the site of a gothic settlement. Since 1999, Polish research has been carried out in excavation XXV located in the western part of Tanais. The initial purpose of the work was to verify the route and structure of the western fortifications, but next to the city gate, a stone and wooden bridge was discovered, a unique engineering work in the ancient world, and a detailed archaeological work was begun in its

surroundings. During these works, irregular, clay mortar, masonry walls were discovered, which were the subject of our research. We do not clearly know the purpose of these constructions; however, there are indications that they had different purposes, for example protective and separating functions [9].

Heretofore, conservation works at the Tanais site carried by the authors consist of two seasons in years 2016–2017. The first season was oriented on detailed documentation with a 3-d scanner [7]. One of the outcomes of that documentation is a three-dimensional model of the excavation, which allows performing precise measurements of structures located inside (Fig. 4).



Fig. 4. Three-dimensional model of archaeological excavation in Tanais, Russia. A box indicates an area of conservation work performed in 2017.

Conservation work carried out in the 2017 season was focused on the chamber located in the north-east corner of the excavation (Fig. 4). A partial reconstruction was performed with a semi-anastylosis method using clay mortar stabilised with lime and cement. Due to the trial stage of conservation work, the pointing with clay mortar, which is a stage of the conservation procedure described in the previous parts, was not applied. Results of the conservation work are presented in the Fig. 5. For the following season it is planned to verify and evaluate the work from the previous season. If it is necessary, the conservation assumptions will be modified for upcoming applications in this excavation.



Fig. 5. Walls of the chamber located in the Tanais archaeological excavation before (on the left) and after (on the right) conservation work in 2017.

5 Conclusions

Conservation of ancient architectural monuments is an issue that requires broad knowledge and experience. The article presents assumptions that should be followed during conservation of irregular masonries located in the archaeological excavations as well as stages of conservation work that arise from them. The given methodology is a result of the authors' experience gained during many years of studies and experiments performed in the frames of conservation projects. It derives from and it is fully consistent with international treaties related to conservation of archaeological monuments.

Appropriate conservation of ancient structures that is related to the improvement of its durability and strengthening, is a rightful implementation of protection of cultural heritage. Proper exhibition of ancient architectural monuments has enormous educational value. Protection and preservation of monuments for further generations is the most precise application of the principles of sustainable development.

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