



Research paper

Conservation works in Tanais archaeological site in years 2016–2019

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Abstract: The article presents and describes the methodology of the conservation of stone structures that are architectural monuments discovered as part of the work carried out during archaeological excavations in Tanais. The authors' experiences presented in the article result from many years of cooperation between the Faculty of Civil Engineering at Warsaw University of Technology and the Antiquity of Southeastern Europe Research Centre at the University of Warsaw. Examples of preserved masonry structures come from an excavation in Tanais near Rostov-on-Don. Works on stone structures located in the area of archaeological excavation are characterised 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 primary 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. The article presents the procedures that should be used to conserve this type of structure and the specific sustainable technological and material solutions used in the shown objects.

Keywords: conservation, ancient structures, stone structures, earth-based mortar

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1. Introduction

The European Convention on the Protection of the Archaeological Heritage [1], drawn up in 1992, recalls that archaeological heritage is of fundamental importance to the knowledge of the history of mankind. Its protection and reliable research are the obligations of all responsible for the scientific truth. According to the convention, the subject of the archaeological heritage is 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. Among the most significant traces of the ancient epochs and civilizations are architectural and structural monuments that are evidence of their creators' technological development, residents' standard of living, 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. To preserve the archaeological heritage, being part of the cultural heritage, and 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 artifacts (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 surrounding, historical and geographical context, shows the whole truth about the historic building and is a much more complete form of education and promotion of monuments [2]. All of these recommendations imply the necessity of many interdisciplinary activities, including engineering ones, which include proper analysis, and often also necessary changes in development plans for areas in 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 conservators should follow when dealing with irregular stone masonry in the area of archaeological excavations. This methodology results from experience and conclusions from the authors' conservation work at archaeological sites in the Black Sea area. The research was carried out as part of conservation missions by the Division of Fundamental of Building of the Civil Engineering Faculty of the Warsaw University of Technology in cooperation with the Institute of Archaeology of the University of Warsaw and the Antiquity in Southeastern Europe Research Centre (Conservation Mission in Tanais near Rostov-on-Don since 2016 till 2019). The building

structures preserved as part of the research were relics of urban buildings from the period of the Bosphorus of Kimmer, from the 5th century BC to the 5th century AC. The ancient city of Tanais was formerly located at the Azov Sea's shore. Due to the area's geological changes, 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 (present Antiquity of Southern Eastern Europe Research Centre) and the Institute of Archaeology. Greek settlers founded the city of Tanais at the beginning of the 3rd century BC. It existed until the middle of the 3rd century AD, when Sarmatian tribes probably destroyed it. In the second half of the 4th century and 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 Western Tanais. The initial purpose of the work was to verify the route and structure of the western fortifications. Still, next to the city gate, a stone and wood bridge was discovered, a unique engineering work in the ancient world and detailed archaeological work was begun in its surroundings. During these works, irregular, earth-based mortar, and masonry walls were discovered, which were the subject of our research. We do not know the purpose of these constructions; however, there are indications that they had different uses, for example, protective and separating functions [17–19].

2. Materials and methods

2.1. The state of preservation of the ancient architectural object

One of the most significant 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 service 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 positive (repairs, adaptations) and destructive (demolition or warfare) impact on maintaining the technical condition. Due to the technical condition, antique architectural monuments can be divided into four groups:

- monuments that do not require (or require minimal) 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 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 several

factors destructive to the monuments. In the case of structures located in Tanais in Russia, it was:

- biological destruction, caused by the damaging effects of green plants, lichens, and weeds growing in spring in the excavation;
- high temperatures in the summer, with strong solar radiation;
- low temperatures in winter, with snowfall and negative temperatures causing freezing of water;
- heavy rainfall in autumn and spring.

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, and 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 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). Washouts are particularly destructive phenomena in the tested irregular walls made on earth-based mortar.

2.2. Characteristics of irregular masonry in Tanais in Russia

One common type of ancient masonry structures exposed as part of archaeological excavations is irregular masonries. In the case of the site where the research was carried out, they were made of ashlar and stones from various limestone rocks, unworked or roughly worked [3], primarily unsorted, of different structures, degree of sedimentation, porosity and absorbability, and, what is associated with it, humidity. Some types of rocks from which masonry elements were made also showed granular disintegration. An earth-based mortar from earth and sand found in the surrounding soil was used as the binder. Such type of material is more and more commonly used not only in the form of masonry mortar [4, 5] but also in plasters [5], rammed earth walls [6–8], or block and cobs as a sustainable one. This irregular masonry was classified according to the Italian code (MIT 2009) as a type A (irregular stone masonry, with pebbles, erratic and irregular stone units) [9] and according to classification based on the characteristics of their sections [10, 11] as multi (three or more) leaves wall with the connection. Such a wall has low strength, internal cohesion, 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.

The specificity of the irregular masonries and their structural and physical properties make their conservation a complex and challenging process. The primary 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, reprofiling with the removal of destructive plant interactions.

2.3. Stages of conservation work

Based on the conservation assumptions described in more detail in the authors' previous publications, especially in [12], it is possible to specify the actions necessary to take to effectively protect and carry out the conservation of historic structures made in the technology of irregular stone walls. These include the following conservation activities:

- 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, their location in the plan, preparation of geometrical survey, drawing, and photographic documentation. A specific form of measurement, drawings, and photographic documentation preparation is the digitalization of the excavation area (masonry structures) using 3D laser scanning [13].
- Preparation of the appropriate mortar (specially modified cement and lime stabilized) earth-based mortar fulfils all necessary conditions for sustainable conservation [14–16]. The actual receipt is always chosen based on the study of the earth from excavation and later laboratory examinations based on the number of codes and standards [17].
- The reprofiling of existing masonry parts with the anastylosis or semianastylosis method, using prepared mortar.

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:

- rebuilding, bonding, and consolidation with appropriate mortar;
- pointing – placing a pointing mortar on a fresh grout;
- joints complementation with pointing mortar after grout hardened;
- mechanical cleaning;
- hydrophilization treatment;
- additional excavation slop protection.

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

3. Results

Hitherto, the authors' conservation works at the Tanais site consist of three seasons from 2016–2019. The first season was oriented on detailed documentation with a 3-d scanner. One of the outcomes of that documentation is the three-dimensional model of

the excavation, which allows precise measurements of structures located inside (Fig. 1). An important advantage of using 3D scanning in archaeological research is measurement range. The technology allows the device to operate from 50 cm to 330 m (Faro Focus X300). The measurement data obtained by the laser scanner is of high accuracy. The 3d scanner uses a single point accuracy of ± 2 mm at a distance of 50 meters from the scanner at a measurement speed of up to ~ 1 mln per second. Mass measurement of the geometric characteristics of the excavation site allows for a detailed investigation of the residue of the structure of the site. 3d scans of the site were done in colour. Thanks to the built-in camera, it is possible to colour point cloud obtained in the first stage with images. Images taken by the scanner, once assembled, create a 360 panorama. Such imagery can be used to visualize the state of objects in the excavation site [13].

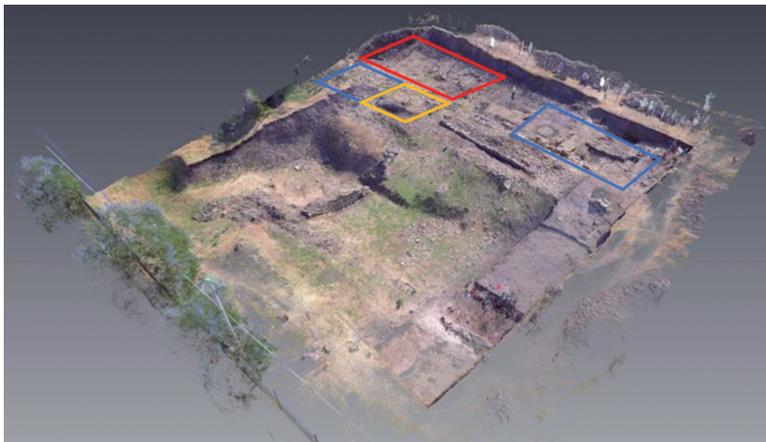


Fig. 1. Three-dimensional model of archaeological excavation in Tanais. A red box indicates an area of conservation work performed in 2017, a yellow area of conservation works completed in 2018 and a blue one in 2019 [17]

Conservation work carried out in the 2017 season was focused on the chamber located in the northeast corner of the excavation (Fig. 1). A partial reconstruction was performed with the semianastylosis method using an earth-based mortar stabilized with lime and cement. The bottom part of the reconstructed walls (foundation) was originally preserved in these walls. The upper parts were reconstructed using stones located close to these structures and between the original and reconstructed parts small ceramic remains were used. Due to the trial stage of conservation work, the pointing with earth-based mortar, a step of the conservation procedure described in the previous parts, was not applied. The results of the conservation work are presented in Fig. 2.

After a year, minor superficial scratches were observed, and about ten masonry elements (stones) were detached, so some works in 2018 were oriented on the reconstruction of these elements. This year, the conservation of further parts of the uncovered structures (yellow box in Fig. 1) was also started. This masonry structures showed a very far-reaching disintegration of its internal structure. They were preserved only in the near-surface areas



Fig. 2. Walls of the chamber located in the Tanais archaeological excavation before (on the left) and after (on the right) conservation work in 2017

and were in poor technical condition. The wall was an irregular, three-layered wall - the faces of the wall were made of massive stones and the infill of finer stones and earth-based mortar. Visible faces of the masonry were not preserved along the entire length, and an original binder was washed out, so the rescue reprofiling of the masonry was necessary.

The work carried out this year consisted of 3 parts:

- 1) preparation of the masonry for conservation work (removal of the layer of stones protecting the excavation, removal of plants);
- 2) the conservation work;
- 3) protection of the trench wall (covering with a layer of stones).

The state of the structure before and after the conservation work can be seen in Fig. 3.



Fig. 3. Wall located in the Tanais archaeological excavation before (on the left) and after (on the right) conservation work in 2018

After the restoration activities in 2017 and 2018, no significant damage, superficial scratches or detachment of the wall elements (stones) were observed. There was also no visible destruction of the wall by atmospheric conditions and salt efflorescence on the face of the wall. Therefore, the properties of earth-based mortar in terms of mechanical, technological, durability and compatibility issues may be assessed as satisfactory. In 2019

the reconstruction of a further part of the stone structures (the area marked in blue in Fig. 1) was started.

A part of the structure required the reprofiling of the outer layers, which was carried out using existing elements and elements near the wall, being its probable part of it (semianastylosis). Following the original technology, the substructure (foundation) of the wall was made of large stone elements. The infill of the wall was made of rubbles stabilized with mortar.

The work's second part was the protection and strengthening of stone structures. It was necessary to temporarily secure the detached masonry elements in the corner of the room (left blue area in Fig. 1). Anastylosis (re-alignment) of the masonry elements that needed preservation was performed. Original masonry elements were used, which had become detached from the overall wall due to weather conditions.

As the last part of the conservation work, the protection and stabilization of a section of the eastern side of the excavation were carried out (right blue area in Fig. 1). A retaining wall was constructed from stone elements in the trench (lying loosely and not connected with the existing masonry relics) and outside the excavation. The construction of the masonry is layered, in the lower part made from 2–3 rows of elements, in the upper part from one row of stone. The state of the wall before and after the conservation work can be seen in Fig. 4.



Fig. 4. Wall located in the Tanais archaeological excavation before (on the left) and after (on the right) conservation work in 2019

The final stage was the mechanical protection of the excavation and masonry structures located in the excavation. A layer of loose stones was used as a protection layer.

4. Discussion

Conservation of ancient architectural monuments is an issue that requires broad knowledge and experience. The article presents assumptions that should be followed during the conservation of irregular masonries located in the archaeological excavations and the stages of conservation work that arise from them. Given methodology is a result of authors' experience gained during many years of studies and experiments performed in the frames of

conservation projects. It derives and is entirely consistent with international treaties related to the conservation of archaeological monuments.

Appropriate conservation of ancient structures, related to improving their durability and strengthening, is a proper implementation of protection of cultural heritage. A good 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. At the same time, it is essential to use sustainable materials and technologies.

References

- [1] Council of Europe European Convention on the Protection of the Archaeological Heritage (Revised). European Treaty Series, 1992, no. 143.
- [2] C. Akca, B. Sayin, and B. Yildizlar, “The conservation and repair of historical masonry ruins based on laboratory analyses”, *Construction and Building Materials*, vol. 132, pp. 383–394, 2017, doi: [10.1016/j.conbuildmat.2016.12.002](https://doi.org/10.1016/j.conbuildmat.2016.12.002).
- [3] L. Dipasquale, L. Rovero, and F. Fratini, “Ancient stone masonry constructions”, in *Nonconventional and Vernacular Construction Materials. Characterisation, Properties and Applications*, K.A. Harries and B. Sharma, Eds. Elsevier, 2016, pp. 301–332.
- [4] G. Azeredo, J. C. Morel, and N. P. Barbosa, “Compressive strength testing of earth mortars”, *Journal of Urban and Environmental Engineering*, vol. 1, no. 1, pp. 26–35, 2007, doi: [10.4090/juee.2007.v1n1.026035](https://doi.org/10.4090/juee.2007.v1n1.026035).
- [5] M. S. Lekshmi, S. Vishnudas, and D. Nair, “Experimental Study on the Physical Properties of Mud Mortar in Comparison with the Conventional Mortars”, *Civil Engineering and Urban Planning: An International Journal*, vol. 3, no. 2, pp. 127–135, 2016, doi: [10.5121/CIVEJ.2016.3211](https://doi.org/10.5121/CIVEJ.2016.3211).
- [6] B. Windstorm and A. Schmidt, “A Report of Contemporary Rammed Earth Construction and Research in North America”, *Sustainability*, vol. 5, no. 2, pp. 400–416, 2013, doi: [10.3390/su5020400](https://doi.org/10.3390/su5020400).
- [7] C. E. Cautius, “Rammed Earth: Adaptations to Urban Toronto”, M.A thesis of Architecture, University of Waterloo, Ontario, Canada, 2014.
- [8] C. Jayasinghe, M. T. R. Jayasinghe, B. Dissanayake, and D. Jayathilake, “Use of Recycled Building Demolition Waste in Stabilized Rammed Earth”, *Masonry International*, vol. 31, no. 1, pp. 17–26, 2018.
- [9] F. Vanin, A. Penna, and K. Beyer, “Equivalent-Frame Modeling of Two Shaking Table Tests of Masonry Buildings Accounting for Their Out-Of-Plane Response”, *Frontiers in Built Environment*, vol. 6, no. 42, pp. 1–18, 2020, doi: [10.3389/fbuil.2020.00042](https://doi.org/10.3389/fbuil.2020.00042).
- [10] A. G. Costa, J. Guedes, and H. Varum, Eds., *Structural Rehabilitation of Old Buildings*. Springer, 2014, pp. 109–130, doi: [10.1007/978-3-642-39686-1](https://doi.org/10.1007/978-3-642-39686-1).
- [11] L. Binda, G. Cardani, A. Saisi, and C. Groot, “A classification of structures and masonries for the adequate choice of repair”, in *International RILEM Workshop on Repair Mortars for Historic Masonry*. Delft, The Netherlands: RILEM Publications SARL, 2009, pp. 20–34.
- [12] W. Terlikowski, M. Matera, K. Wasilewski, M. Gregoriou-Szczepaniak, and E. Sobczyńska, “Conservation of irregular stone masonry in Tanais in Russia”, in *MATEC Web of Conferences*, vol. 196, 2018, doi: [10.1051/mateconf/201819602041](https://doi.org/10.1051/mateconf/201819602041).
- [13] W. Terlikowski, M. Gregoriou-Szczepaniak, E. Sobczyńska, and K. Wasilewski, “Advantages of using 3d scanning in the survey of architectural monuments on example of archaeological sites in Egypt and Russia”, *Archives Of Civil Engineering*, vol. 67, no. 1, pp. 189–201, 2021, doi: [10.24425/ace.2021.136468](https://doi.org/10.24425/ace.2021.136468).
- [14] TC 203-RHM, *Repair mortars for historic masonry - State of the Art Report of RILEM Technical Committee TC 203-RHM*, P. Maurenbrecher and C. Groot, Eds. RILEM Publications SARL, 2016.
- [15] M. Apostolopoulou, E. Aggelakopoulou, A. Bakolas, and A. Moropoulou, “A compatible mortars for the sustainable conservation of stone in masonries”, in *Advanced Materials for the Conservation of Stone*, M. Hosseini and I. Karapanagiotis. Berlin/Heidelberg, Germany: Springer, 2017, pp. 97–123.

- [16] J. D. Rodrigues and A. Grossi, “Indicators and ratings for the compatibility assessment of conservation actions”, *Journal of Cultural Heritage*, vol. 8, no. 1, pp. 32–43, 2007, doi: [10.1016/j.culher.2006.04.007](https://doi.org/10.1016/j.culher.2006.04.007).
- [17] E. Sobczyńska, W. Terlikowski, and M. Gregoriou-Szczepaniak, “Stability of treatment from earth-based mortar in conservation of stone structures in Tanais, Russia”, *Sustainability*, vol. 13, no. 4, pp. 1–20, 2021, doi: [10.3390/su13042220](https://doi.org/10.3390/su13042220).
- [18] E. Papuci-Wadyka, M. Vickers, J. Bodzek, and D. Braund, *Pontika 2008: Recent Research on the Northern and Eastern Black Sea in Ancient Times*. Oxford : Archaeopress, 2011.
- [19] T. Scholl, “Tanais – excavations in 2010”, in *Swiatowit: Annual of the Institute of Archaeology of the University of Warsaw*, vol. 8, M. Stepiński, Ed. Warsaw University. Institute of Archaeology UW, 2011.

Prace konserwatorskie w miasteczku archeologicznym w Tanais w latach 2016–2019

Słowa kluczowe: konstrukcje starożytne, konstrukcje kamienne, zaprawa gliniana, konserwacja

Streszczenie:

W artykule przedstawiono i opisano metodologię konserwacji zabytkowych murów kamiennych będących zabytkami architektury odkrytych w ramach prac prowadzonych podczas wykopalisk archeologicznych w Tanais. Doświadczenia autorów przedstawione w artykule są wynikiem wieloletniej współpracy Wydziału Inżynierii Lądowej Politechniki Warszawskiej z Ośrodkiem Badań nad Starożytnością Europy Południowo-Wschodniej Uniwersytetu Warszawskiego. Przykłady zachowanych konstrukcji murowanych pochodzą z wykopalisk w Tanais koło Rostowa nad Donem. Prace przy obiektach kamiennych zlokalizowanych na terenie wykopalisk archeologicznych charakteryzują się wyjątkową specyfiką obejmującą zarówno kwestie formalne, wynikające z międzynarodowych norm i umów regulujących konserwację zabytków, jak również kwestie techniczne i środowiskowe. Do podstawowych zagadnień technicznych należy zapewnienie bezpieczeństwa dalszych prac wykopaliskowych, zabezpieczenie konstrukcji murowanych przed niszczącym działaniem warunków atmosferycznych oraz przygotowanie konstrukcji do ewentualnej ekspozycji w parkach archeologicznych organizowanych na terenie wykopalisk. W artykule przedstawiono procedury, jakie należy zastosować w celu konserwacji tego typu konstrukcji oraz rozwiązania technologiczne i materiałowe zastosowane w omawianych obiektach.

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