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## CURRENT STATE OF TECHNOLOGY AND METHODS OF RESTORATION OF ARCHITECTURAL MONUMENTS

*The article presents the results of the analysis and generalization of the current state of technology and methods of restoration of architectural monuments. It is shown that the prospects for the development of the construction complex of Ukraine determine the need for the creation and functioning of a system of highly effective technologies for the restoration of architectural monuments, which is adapted to the specific characteristics and parameters of the object and the subject of restoration. The formation of such a system is carried out on the principles of innovative efficiency of restoration technologies from the set of existing technologies in the construction industry, which, in turn, is formed under the influence of global progress in the construction and technological sphere. A systemic interrelationship between types of restoration and methods of restoration, as construction-technological systems, is established. The established relationship is taken as the basis of organizing the system of methods of restoration of architectural monuments. The impact of scientific and technical progress in the field of construction on the multiplicity of methods of execution and mechanization of restoration processes has been established, as one that goes to infinity, which translates the existing system of methods into the category of large, complex and open systems with a disordered structure.*

*Keywords: technology; restoration; architectural monuments; methods of execution and mechanization of restoration processes*

**Statement of the problem.** According to modern ideas, restoration, as a special complex of construction and installation works aimed at the reconstruction, strengthening of destroyed, damaged or distorted buildings and structures, related to monuments of architecture or history, is an equal component of a more general system - construction - a branch of material production, covering new construction, reconstruction, repair and restoration completed and constructed [1, p. 5]. Therefore, the current state of technology and methods of organizing the restoration of monuments of architecture and history almost fully correspond to the modern scientific, technical and technological level of development of the construction industry in our country.

The scientific, technical and technological commonality of the object and the subject of construction technology research, applied in the conditions of restoration, new construction or reconstruction, determines the need to consider the prospects for the development of technologies and methods of organizing the restoration of architectural monuments in relation to the main directions, characteristics and parameters of global progress in construction and technology sphere and development prospects of the construction complex as a whole.

**Relevance and purpose of the study.** Many works have been devoted to the problem of improving the methods of restoration of buildings and structures [1-6], but the analysis of these scientific studies shows the diversity of construction and technological solutions and technologies for the implementation of restoration processes and methods of organizing the restoration of architectural monuments, their logical inconsistency, which consists in underestimating the importance of the formation general representation regarding the conditions of its implementation.

**Purpose of the article.** The effectiveness of restoration technologies, along with the availability of modern methods of execution and mechanization of restoration processes, largely depends on the level of orderliness of the system of methods, as a large complex system, and which is also constantly developing.

**Research methods.** The research is based on a general scientific method - analysis and generalization, development of classifications.

**Basic material and their results.** If the general prospects for the development of the construction complex of our country determine the need for the existence and functioning of a system of highly effective technologies for the restoration of monuments of architecture and history, as a technical and economic limitation, then taking into account global progress in the construction and technological sphere contributes to the formation of such a system based on the principles of innovative efficiency - the existing system of methods restoration is improved by the complex implementation of new technologies, "... having a high degree of spread in the practice of ... construction, adapted to the existing technological and technical level of construction production, as well as having highly predictable efficiency, confirmed by practical experience" [2, p. 241].

Restoration of architectural monuments, with its substantive meaning, covers [3]:

- restoration of individual architectural objects - buildings and structures classified as architectural and historical monuments, to preserve their historical and cultural significance;

- restoration of an interconnected complex of buildings and structures:

- ✓ development of a historical populated area, preserving the historical area in whole or in part and included in the List of Historical Populated Places of Ukraine [5];

✓ architectural ensemble - historical area - part of a populated area that has preserved cultural heritage objects and the associated plan and form of development.

Modern ideas about an architectural monument as an object of cultural heritage protection, as well as the concept of their restoration as a whole, developed in the second half of the 19th – early 20th centuries and found their logical conclusion in the World Charter of Restorers, adopted at the II World Congress of Restorers, held in Venice in 1964 [6].

Currently, the technology for performing construction processes and methods for organizing the restoration of architectural monuments are regulated by state regulations [7] and numerous practical recommendations and methods [8-14], including foreign authors [15-18], and are based on the principle of guaranteed preservation of historical authenticity of the architectural monument and provisions taking into account [19, 20]:

- the accepted method of restoration of an architectural monument;
- original purpose, space-planning and structural design of the architectural monument, taking into account previously completed modernizations and improvements (repair, reconstruction or restoration);
- the initial technique for performing construction processes and the method of erecting an architectural structure, its parts and structures;
- degree of preservation of the monument, major damage and defects.

The initial data for the design and implementation of restoration are established on the basis of archival, archaeological, architectural, technical and other studies and research [14-23].

The formation and systematization of initial data on the restoration object is carried out through the analysis of design and estimate documentation and survey materials of the object being restored, based on the results of which the following are determined [12]:

- method of restoration of an architectural monument;
- architectural, space-planning and design parameters of the restoration object - the nature of the location and density of the territory; space-planning and design characteristics and parameters; initial (at the time of construction) category of general spatial rigidity and stability; the nature and degree of weakening of the spatial rigidity of the frame; technical condition of load-bearing and enclosing structures and the entire architectural monument as a whole;
- architectural and historical value of structures, parts, structural and architectural elements of an architectural monument, which are the subject of cultural heritage protection;
- type, design and current technical condition of the main load-bearing and enclosing structures, finishing coatings and engineering systems;

- list and scope of special work and measures to ensure the strength and stability of load-bearing structures and an architectural monument during its restoration (installation of security reinforcement, temporary and design strengthening of structures and foundations, monitoring and scientific support of restoration, etc.);
- technological parameters of the scope of work - structure and volumes for individual types of work and structures, shift volumes of work, timing of work, composition and availability of mechanization equipment and qualified teams of workers, suppliers of building materials and products, possible subcontractors and contractors;
- organizational conditions and restrictions of construction production - the nature and parameters of tightness in areas of transportation, storage, large-scale assembly, work and workplaces of workers; restrictions imposed on the organization and methods of work by the specific conditions of restoration of an architectural monument (temporary mode of work, inadmissibility of the formation of dust, fumes, gases, aerosols, a ban on dynamic impacts (shock, vibration) and the formation of noise.

Restoration technology, as an interconnected complex of special restoration work of a certain essence, structure and combination, including methods for performing and mechanizing restoration processes of varying complexity, is determined primarily by the accepted method of protecting a cultural heritage site [7-10, 12-13, 18-20, 23 -24].

In accordance with the Law of Ukraine “On the Protection of Cultural Heritage,” the following methods of protecting cultural heritage objects are distinguished [3]:

- *conservation* - a set of scientifically based measures that make it possible to protect cultural heritage objects from further destruction and ensure the preservation of their authenticity with minimal interference in their existing appearance;
- *museumification* - a set of scientifically based measures to bring cultural heritage sites into a state suitable for excursion visits;
- *adaptation* - a set of research, design, survey and production work to create conditions for the modern use of a cultural heritage object without changing its inherent properties, which are the subject of protection of the cultural heritage object, including the restoration of elements that constitute historical and cultural value;
- *rehabilitation* - a set of scientifically based measures to restore the cultural and functional properties of cultural heritage sites;
- *repair* - a set of design, survey and production work aimed at improving the technical condition and maintaining the operational condition of a cultural heritage object without changing the properties that are the subject of protection of the cultural heritage object;

• *restoration* - a set of scientifically based measures to strengthen (conserve) the physical condition, reveal the most characteristic features, restore lost or damaged elements of cultural heritage objects, ensuring the preservation of their authenticity.

Currently, in normative and scientific-technical literature, restoration is understood as the strengthening and restoration of destroyed, damaged or distorted historical and cultural monuments (architectural structures) in order to preserve their historical and artistic significance and, as a special case, with the aim of returning them to their original appearance. Thus, the problems of restoration of architectural monuments include conservation and restoration of cultural heritage objects, which is accepted in this work as the object of study (Fig. 1).

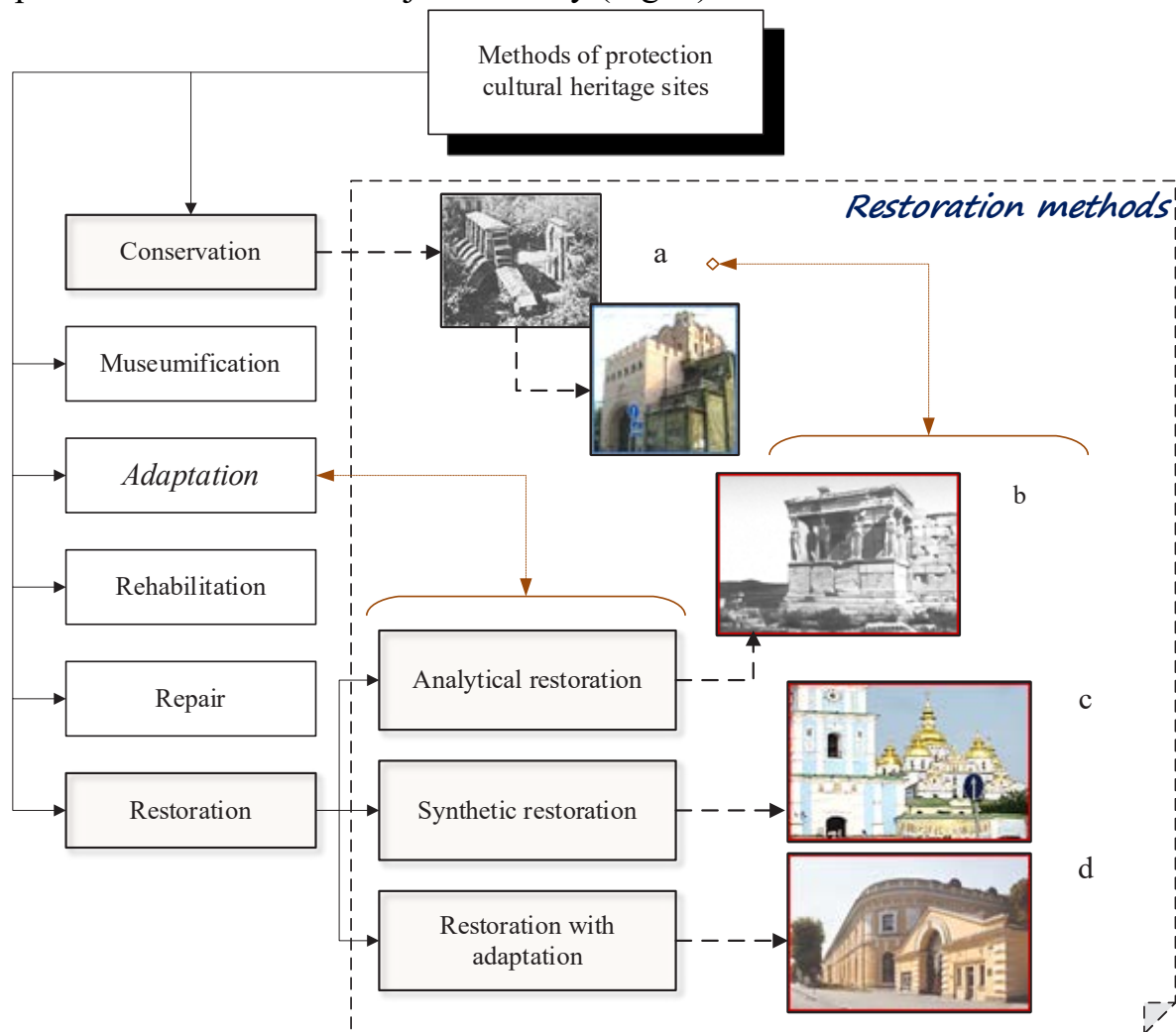


Fig. 1. Systematic relationship between methods of restoration and protection of architectural monuments as objects of cultural heritage:

a – Golden Gate in Kyiv; conservation of an architectural monument by erecting a protective structure over it, stylized to match its original appearance;

b – Portico of the Erechtheion temple in Athens; added parts are highlighted with light material;

c – St. Michael's Golden-Domed Cathedral in Kyiv; almost complete reconstruction of an architectural monument based on surviving drawings, photographs and detailed descriptions;

d – Mystetsky Arsenal in Kyiv; restoration of the Old Arsenal with its adaptation to a cultural and exhibition center

The most common methods of restoration of architectural monuments usually include (Fig. 1):

*conservation* is a set of measures and work that ensures for a long time the preservation of the appearance of an architectural monument (initial or preserved until it is submitted for conservation), its mechanical strength and chemical inertness; At the same time, the following is performed: consolidation of the foundation soil; strengthening walls, piers, arches and vaults; construction of protective pavilions and canopies, as well as other work and activities (Fig. 1, a);

*analytical restoration* is a set of activities and works for a comprehensive study of an architectural monument as a historical document and careful strengthening of the real ancient parts of the monument with minimal intervention and the volume of restoration work; all newly added elements must be highlighted, and all extensions must be made in a modern style (Fig. 1, b);

*synthetic restoration* is a set of measures and work aimed at almost completely recreating an architectural monument in the event of its complete or significant destruction and subject to the availability of reliable information (drawings, plans, photographs, detailed descriptions, etc.) about the appearance of the architectural monument; This method is used as an exception and only for architectural monuments of outstanding national significance (Fig. 1, c);

*restoration with adaptation* is a set of measures and work aimed at adapting an architectural monument to a new purpose and function with the simultaneous restoration of destroyed and lost parts of the monument, restoration or conservation of elements that constitute the subject of protection of a cultural heritage object - its historical and cultural value (Fig. 1, d).

Methods for the restoration of architectural monuments mutually determine the methods of performing the corresponding complexes of restoration processes, determining their essence, structure, necessary combinations and order of implementation (Fig. 2, [12, 22]).

The set of methods used in practice for performing construction restoration processes  $M_j = \{m_j\}$  at the time of the study has an insufficient level of ordering and can only be considered as an open set of possible methods, such that

$$\forall, \vartheta [\exists \{m_j\}_{\vartheta} \in M_j = \{m_j\}; \vartheta = (1, \Theta); j = (1, J)] \quad (1)$$

for any variant  $\vartheta \in \Theta$  of a complex of restoration works and processes, there are corresponding variants of methods for their implementation  $\{m_j\}_{\vartheta}$ , which are elements of the general set of possible restoration methods  $M_j$  - a large and complex system, including a large number of heterogeneous and different-quality elements of a hierarchical structure - methods of implementation and mechanization of processes, methods, techniques and modes of performing individual operations, permissible and



limit values of technological parameters and finished construction products and other elements and subsystems.

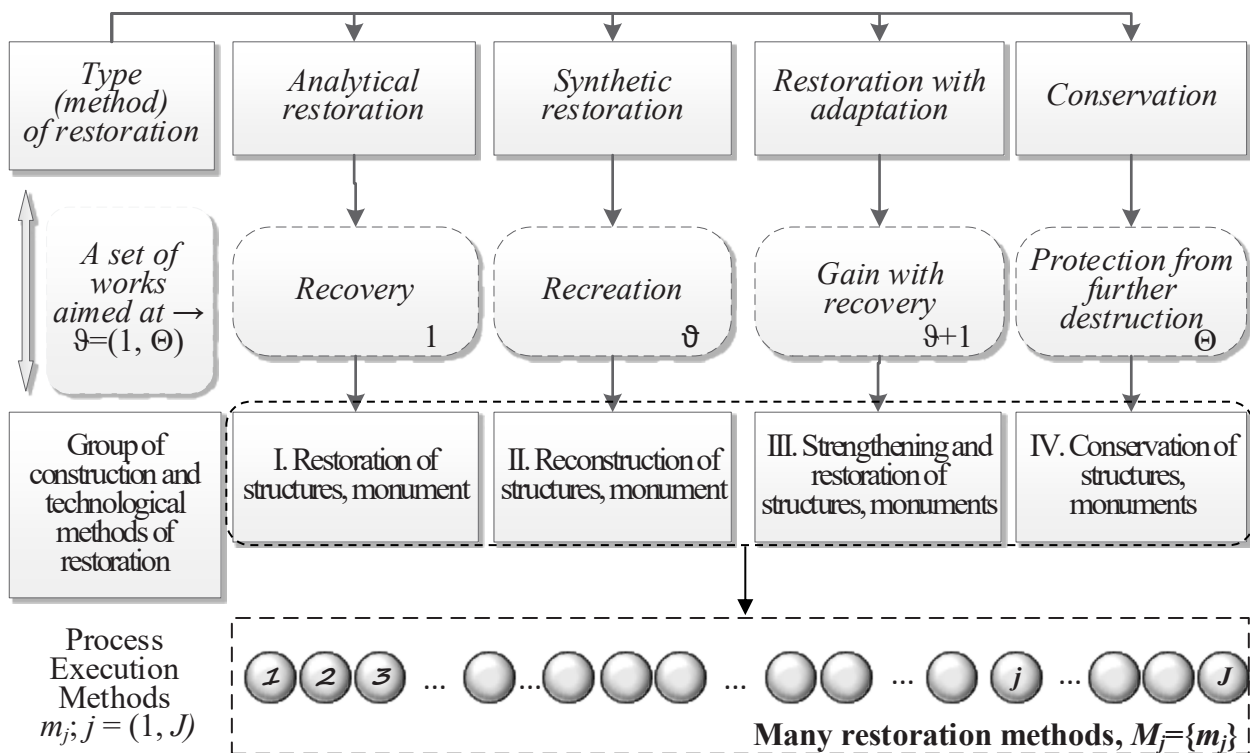


Fig. 2. Systemic relationship between construction and technological restoration methods and types (methods) of restoration of architectural monuments

Thus, the above conditions for the design and implementation of restoration of architectural monuments (see (1)) significantly complicate decision-making processes, which cannot guarantee sufficient completeness of coverage of possible methods for performing restoration processes in their structure and scope of application, which reduces the level of alternativeness of the generated options technologies, and the process of selecting optimal solutions according to technical and economic criteria turns into a formal one and is characterized as unreliable.

Providing general principles for the selection of organizational and technological solutions, assuming the choice of options and multi-criteria technical and economic analysis, in the conditions of selecting alternative options from the general set of methods for performing restoration processes  $\{m_j\}$ , which belongs to the category of *large and complex systems*, is very problematic and assumes the presence, *in - firstly*, an almost complete base of methods and standard solutions, the presence, *secondly*, of methodological support in a modern digital format and powerful material modeling tools, and also, *thirdly*, a very large experience of the designer and producer of the work.

At present, the possibilities for implementing the above conditions, neither in the first, nor in the second, nor in the third point, have been fully created.

Available generalizations of methods for performing restoration processes [9, 13, 19, 25], including those previously carried out by the author [12], do not have a sufficient level of generality, since all of them, despite their large number and detail, are devoted to individual elements and subsystems - methods of strengthening, strengthening foundations, foundation soils, masonry walls, arches, vaults, methods of replacement, repositioning of structural elements, restoration of plaster and paint coatings, frescoes, mosaics, etc.

An analysis of modern practical experience in the restoration of architectural monuments, set out in the works of [4, 13, 25, 26] and other domestic and foreign authors, indicates that recently, the general set of methods for performing construction restoration processes has been *significantly expanded* by the introduction (Fig. 3):

- new methods of performing and mechanizing construction processes, including those based on new principles, processes or phenomena, namely:

- a) complex mechanized methods for performing labor-intensive restoration processes using modern construction machines and mechanisms of a wide range and functions, including manipulators and robotic complexes (Fig. 3, a);

- b) systems of manual, electrified and hydraulic tools for performing basic and auxiliary processes and operations - drilling holes, cutting stone, concrete, metal, destroying oversized objects, peeling coatings, cleaning surfaces, priming, impregnating structures, applying coatings, injection of cracks and so on. (Fig. 3, b);

- methods based on the use of new materials, semi-finished products, products and structures that change the structure and modes of restoration processes and operations, namely:

- c) anchoring, impregnation, waterproofing, sanitizing and other systems and technologies (see Fig. 3, c);

- d) high-strength, super-strength and ultra-strength concrete, super-strength metal, non-metallic and composite products and structures, ultra-lightweight structures and other solutions (see Fig. 3, d).

**Conclusions.** Consequently, the total set of methods for performing construction restoration processes under the influence of scientific and technological progress in construction and other related areas of material production is rapidly increasing and tends to infinity -  $M_j = \{m_j\} \rightarrow \infty$ . In general, it can be summarized, that the methods of restoration of architectural monuments are mainly based on the latest achievements of science and technology and together represent a *large and complex system of disordered structure*.





Process Execution Methods  $m_j, j = (1, J)$



implementation



testing

development

new solutions

$M_j = \{m_j\} \rightarrow \infty$

Scientific and technical progress

e

Fig. 3. New means of mechanization (a, b) and technologies for performing (c, d) restoration processes, significantly expanding the original set of restoration methods (e - structural and logical diagram)

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## **СУЧАСНИЙ СТАН ТЕХНОЛОГІЇ ТА МЕТОДІВ РЕСТАВРАЦІЇ ПАМ'ЯТОК АРХІТЕКТУРИ**

У статті викладено результати аналізу та узагальнення сучасного стану технології та методів реставрації пам'яток архітектури. Показано, що перспективи розвитку будівельного комплексу України визначають необхідність у створенні та функціонуванні системи високоефективних технологій реставрації пам'яток архітектури, яка адаптована до специфічних характеристик і параметрів об'єкту та предмету реставрації. Формування такої системи здійснюється на принципах інноваційної ефективності технологій реставрації із множини існуючих технологій у будівельній галузі, яка, у свою чергу, формується під впливом загальносвітового прогресу у будівельно-технологічній сфері. Встановлений системний взаємозв'язок між різновидами реставрації та методами реставрації, як будівельно-технологічних систем.

Встановлений взаємозв'язок прийнятий в основу упорядкування системи методів реставрації пам'яток архітектури. Встановлено вплив науково-технічного прогресу в галузі будівництва на множинність методів виконання і механізації реставраційних процесів, як такої, що прямує до безкінечності, що переводить наявну систему методів у категорію великих, складних і відкритих систем, що мають неупорядковану структуру.

Ключові слова: технологія; реставрація; пам'ятники архітектури; методи виконання і механізації реставраційних процесів.

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