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ASPECTS ON PRESERVING WALL PAINTINGS (EXAMPLE OF UKRAINE AND CHINA)

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Abstract
Analysis of tested restoration methods and their effects on historical fresco restoration cycles emphasized the specification of previous achievements and losses in the restoration industry. As examples, the wall paintings of the Dunhuang sanctuaries in China and the Trinity Gate Church in Kyiv were analyzed. Based on modern comprehensive research, periodic photo documentation and scientific monitoring of the monument, the main factors influencing the preservation of the mural of the Trinity Gate Church have been identified in the context of studying the problems of the current state of monumental painting. With a perspective on the development of heritage preservation measures and recommendations for further conservation, the study aims to determine the most effective ways to maintain the artwork's original state. The original chemical composition of the mineral pigments of the sanctuaries of Dunhuang and the Trinity Gate Church was determined. The common problems of the state of emergency for the wall paintings of Dunhuang and the Trinity Gate Church are outlined.

Keywords*: Conservation issues; Murals; Ukraine; China; Trinity Gate Church; Dunhuang*

Introduction

Despite the distance between the wall paintings of Dunhuang and the Trinity Gate Church in Kyiv and the difference in techniques and chemical composition of the base and paints, there are similarities between them. Both face the problem of excessive moisture, dust accumulation and the fact that these wall paintings were in a state of emergency for a long time, resulting in losses and damage.

The shortcomings of knowledge in the field of technique and technology of painting materials especially affected monumental paintings. Firstly, the technique and technology of the old masters were practically lost, which contributed to the unsuccessful experimental activity in the practice of wall painting. The lack of thorough knowledge about the value of authentic wall paintings, the chemical composition of the base and the paints led to the emergency condition of

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the wall paintings of the Dunhuang sanctuaries and the fresco wall paintings of the ancient princely and baroque churches of Kyiv.

Technological mistakes made by restorers of the 19th century became fatal for many outstanding monuments of Ukrainian monumental painting. Experimental works of F.G. Solntsev in the St. Sophia Cathedral of Kyiv in 1843–1853, A.V. Prakhov in the St. Cyril Church in 1882–1884 testify to the lack of professional knowledge in the field of natural sciences – chemistry, physics, biology. Applying the same methods and recipes that have been used since the Middle Ages during the painting restoration: alcohol, potash, salicylic acid, soda, wooden and metal scrapers, breadcrumbs and lost places were often redrawn by non-professional artists [1].

Already a year later, the restored frescoes were covered with mold and blackened, as happened with the renewed fresco of the St. Sophia Cathedral in 1849 [2]. During such "restoration", large areas of priceless paintings of past centuries were irreversibly destroyed. Despite this, their experience cannot be called entirely negative. It became a stage in the formation of the restoration industry and an example of the restoration of monumental paintings in the 19th century. Under the influence of archaeological experience in restoration, techniques of layer-by-layer removal of late records, accurate tracing and copying with paints in life-size, photographing of ancient wall paintings and the practice of keeping protocols of restoration works were approved. Thanks to further research work and the development of the restoration business, entire artistic eras have become the property of modern humanity.

Professional chemists and technologists such as A. Keim, F.F. Petrushevskyi, M.I. Lavrov, D.Y. Kiplik, V.O. Shchavinskyi, V.Ye. Lokhanko, began to study the chemical composition of paints, technological properties of solvents, varnishes and primers at the turn of the 19th – 20th centuries. During this period, the means and methods of restoration of wall paintings began to be actively studied: fixing the plaster layer, dismantling and mounting fragments of monumental paintings, which had not been used until then. At the same time, ensuring the integrity of the monument, its specificity, texture and picturesque components were taken into account. During the restoration process, it was noticed that some tools and materials harm the state of the monument already after its completion. Thus, the cleaning of murals with alkalis and soap, which were traditional in the practice of restoration, became the cause of the destruction of works of monumental painting, acting on the soil and pigments of the paint layer. The use of acids, in turn, led to the salinity of the paint layer, which required further additional, dangerous for painting, operations to remove them.

The purpose of the study was to highlight the problems of preservation and restoration of wall paintings in the example of Dunhuang cave sanctuaries and the Trinity Gate Church, to describe the original composition of the materials. To achieve the goal, sources were studied in the following directions:

1) general aspects of historical and cultural heritage protection and museology [1-6];

2) protection of Ukraine’s and Polish historical and cultural heritage and specifics of historical cities’ development [7-14];

3) issues of works of art and the artistic aspect in restoration [15, 16];

4) aspect of interaction "architectural monument – environment" [17];

5) professional training of restorers, restoration technologies [18 – 25];

6) research of the Trinity Gate Church [29 – 31].

Materials and methods

The purpose of the research led to the use of general scientific research methods, which can be conventionally divided into a group of theoretical methods and a group of practical methods. The group of theoretical methods is the method of historical analysis, cultural analysis, art analysis, comparative analysis and system analysis. A group of practical methods -

the method of natural examinations, the photofixation method, specific restoration methods, the experimental method.

Results and discussion

Study of the materials of the Trinity Gate Church in Kyiv

The first thorough studies of the technology and composition of the materials of the wall painting of the Trinity Gate Church were carried out during the restoration of the monument in the 1950s. In the future, the results of microchemical and microbiological studies were necessarily part of the restoration documentation. Thus, research has revealed that the walls of the church are made of red brick and boulders of crude stone in the traditional for the beginning of the 12th century construction technique "opus mixtum". Interior painting is done over a layer of plaster 2–3 cm thick, which contains identified lime with a filler (quartz sand in the amount of 30%, fraction size 0.1–0.5 mm), vegetable and animal glue. There is also a small amount of small fraction of brick dust (grain size 0.08 – 0.5 mm)[1].

Usually, the composition of plaster, as the basis of wall painting, determines its quality and properties and the choice is dictated by local mineral raw materials and painting techniques. Since ancient times, lime, obtained as a result of burning limestone and its subsequent quenching, was the main component that ensured the strength of the plaster layer and its connection with the masonry [26]. The plaster base was prepared from pure, especially aged, carbonized lime or lime with a filler of sand and organic additives in the form of straw or vegetable adhesives, which were necessarily added to the mixture to increase the strength and plasticity of the lime [27]. Taking into account that the nature of the soil of wall painting is determined by the technique of the future painting and binding substance, identified in the Trinity Church, the composition of the base satisfied painting with fresco or glue paints and is characteristic of the period up to the 17th century [28].

Indeed, already during the examination of the church's paintings in 1956 by A.T. Domnych under a layer of paint and soil of the 18th century fragments of painting belonging to an earlier period were discovered (Fig. 1). At the same time, the extent of the lost original paintings was unknown. As noted in the accompanying restoration documentation, the dating of the original wall painting is not based on any documentary information, however, "F. Umantsev's evidence regarding interior decoration in the 20s and 30s of the 18th century is quite convincing" [28]. Previously, the researchers assumed the tempera technique of performing the original layer of paintings. Later, during the restoration activities in the church in 1973 and 1986, these studies were refined. There were also assumptions about the existence of early fresco paintings in the interior of the church. In particular, this opinion was expressed by the artist-restorer A. Marampolskyi after the survey and restoration of the temple wall painting in 1973 [29]. During sounding surveys of the walls of the lower tier of the church, he discovered fragments of painting close to the frescoes. Thus, a layer of black color was found on various parts of the walls of the southern room and in the room of the northern part, under a layer of later applied plaster, an earlier layer of plaster with paint was found. Laboratory analysis of the composition of the discovered fragment confirmed the similarity to the plaster taken from the altar vault of the second tier of the church. However, a chemical and technological study of the paint layer denied the presence of a fresco painting.

The locations of ancient paintings and later layers were determined by special probes in the paint layer, which are usually carried out by mechanical, dry methods or with the help of organic solvents. According to the results of surveys carried out by restorers in individual

[1] The plaster composition is similar to the composition of individual samples selected from local areas of the 1644 painting of the altar part of the Church of the Savior on Berestov (Kyiv-Pechersk Lavra National Reserve).

areas[2], on most of the ancient masonry of the church, the original plaster with the remains of the original painting, which could date back to the 17th century, was preserved. These assumptions were also confirmed by laboratory studies, establishing the nature of the binding substance of the pigments of the paint layer. A chemical-technological study of the structural layers of the painting showed that a layer of adhesive red ocher and a layer of glue-chalk soil glued with animal glue was applied on top of the plaster. The presence of a red base is a characteristic feature of wall paintings of the 17th century. Ocher, black, red, gray and blue colours were visible on probes. In general, about 100 m² of adhesive painting was discovered by sounding method only on the vaults of the Trinity Church.

Fig. 1. A fragment of a wall painting on the southern wall of the side aisle.

As you know, glue painting is one of the most ancient ways of painting walls and vaults of buildings. This technique was most widely used in Italy, where the climatic conditions contributed to the preservation of paintings of this type, from where it was brought to us by Italian masters. The execution of wall paintings by the method of applying pigments rubbed on a solution of organic glue was the most widespread in ancient Russian medieval temples. Paints were applied to fresh lime plaster and for better adhesion to the surface at the final stage, aqueous solutions of various adhesive substances were added to them, such as decoctions of flax, wheat, or sturgeon glue [30, p. 57 – 72]. In particular, the remains of protein substances of animal origin were found in the composition of the paint layer of fragments found during the excavations of the Assumption Cathedral in 1986.

The new aesthetic concept determined not only a new artistic and aesthetic perception of the pictorial decoration of temples but also led to changes in the technological culture related to the preparation of walls for oil painting. At the end of the 17th century, there was a tendency to simplify the technological production of the plaster base and base for wall painting. One of the

[2] Probe explorations were carried out on the vaults of the altar, sacristy (deaconry) and the central altar in the southern and northern pre-altar volume, in the narthex of the northwestern part, in the side aisle on the southern wall in front of the composition "Faces of the Holy Immaculates", on the eastern part of the vault of the first floor of the side aisle near the entrance to the church on the composition "St. John the Baptist at the head of the high priests and soldiers", on the compositions "The Message of the Apostles", "Baptism of the Ethiopian" on the northern wall and on the southern wall of the vestibule on the composition "God the Father".

reasons for such a transformation is often associated with the Western European practice of preparing walls with lime-sand and lime-gypsum-sand composition, which replaced the extremely time-consuming method of making the base, which existed until the 17th century. However, as analytical studies have shown, the Western European influence almost did not affect the technology of wall preparation in the Trinity Church. During the renewal of the temples of the Kyiv-Pechersk Monastery after the consequences of the fire in 1718, the interior decoration of the church was done with oil paints, while using the old plaster layer.

The oil technique borrowed from Europe, which became widespread in Ukraine at the turn of the XVII-XVIII centuries, was especially widely used to renew earlier paintings. This was explained by the convenience of work since the paints rubbed on oil had a dense color and tone that almost did not change after drying, allowing them to work on the entire surface at the same time. In addition, the oil technique allowed masters to use pigments and materials that could not be used in fresco painting: auripigment, cinnabar, azurite, lead white and saturnine red, varnish etc. Thanks to the specificity of the oil binding substance, artists could always correct previously written or rewrite an unsuccessful place, which was a significant advantage compared to other, difficult-to-perform techniques – frescoes or tempera. Under the influence of Western European culture, the color vocabulary of paintings is enriched with more natural shades, which is due to the desire to convey the "naturalism" of the objects of the image.

The familiarity of Lavra artists with Western European traditions and new methods of image creation significantly expanded the range of creative possibilities in creating volume, modeling form and light and shade and also enriched their painting palette by importing painting materials from abroad. Such paints were called "Venetian" paints, which indicated, in particular, their exceptional quality.

Having become a model of the artistic thinking of its time, the mural of the Trinity Church is distinguished by its bright sound of colour, colorfulness and decorativeness. The color of the wall painting, built in a characteristic range of rich blue, red, green and ocher tones, made in various colour compositions, harmoniously combined with the gold of the background and frame, indicates the complex structure of the paintings. Artists, having at their disposal a relatively small set of pigments, obtained a wide color palette with the help of various artistic techniques. One of the most common is creating color by mixing different pigments. Studies have shown that by using the same set of paints and changing their ratio, artists obtained different colours and shades.

Complex studies of wall paintings became the subject of a scientific study by one of the authors of the article [29, 31].

Some information about the materials of the new painting of the Trinity Church – pigments and binders – was provided by numerous archival sources of the 18th century, stored in fund 128 of the Central State Historical Archive of the city of Kyiv. Thus, separate archival documents contain lists of painting materials used in the palette of the Lavra icon painters – "registers of different paints and other painting accessories". Among them are cinnabar, umber, ochre, indigo, lapis lazuli, orpiment, style de grain, English earth, lead white, minium, Venetian oil, vermilion and lead-tin yellow. This is a traditional set of mineral and organic pigments used in painting since the Middle Ages.

However, even with the list of paints used by the masters when creating the paintings, it is difficult to state with confidence about their composition without the need for chemical analysis of samples and stratigraphic research of the painting.

Thus, the structure of the monumental painting of the Trinity Church was investigated by the method of stratigraphic research with the production of microsections of cross-sections of selected samples of the paint layer, studied in polarized white light and the light of visible luminescence excited by UV rays [29, 31]. The composition of the pigments of the paint layer was determined by the methods of microchemical, thermochemical, luminescence and emission spectral analyses, the composition of the soil was determined by the method of IR spectroscopy.

Research has established that the basis of the painting palette of the interior wall painting of the Trinity Gate Church consists of the following colours: red shades are represented by such pigments as cinnabar, ocher and red marmot; green – verdigris; blue – azurite, smalta; yellow – ocher; black – coal and white – lead bleach, which contains micro impurities of silver in its composition. The presence of orpiment and natural ultramarine pigment was also identified [29]. To avoid the unwanted gloss characteristic of oil painting, artists used a special emulsion consisting of beeswax and Venetian oil (turpentine) for the preparation of paints, which contributed to the formation of a matte surface.

Fig. 2. The image of the "New Testament Trinity" is placed in the conch of the central apse.

The bright blue color that is present in some compositions of the mural is achieved by using ultramarine pigment. Among the other blue pigments discovered and known from the period of the 5th–15th centuries are azurite and smalt (Fig. 2). In particular, smalt, which has been used in painting since 1483, was found mixed with lead white in the areas depicting the sky and water. The spectrum of green colours is represented by a mixture of yellow ocher and azurite, as well as an artificially prepared copper pigment – verdigris, which is found in various compositions of colours in almost all areas of the paintings (Fig. 3). Bright red shades are made with a mixture of colours including cinnabar, red ochre, white lead and carbon black, yellows include orpiment, known since ancient times and ocher [29].

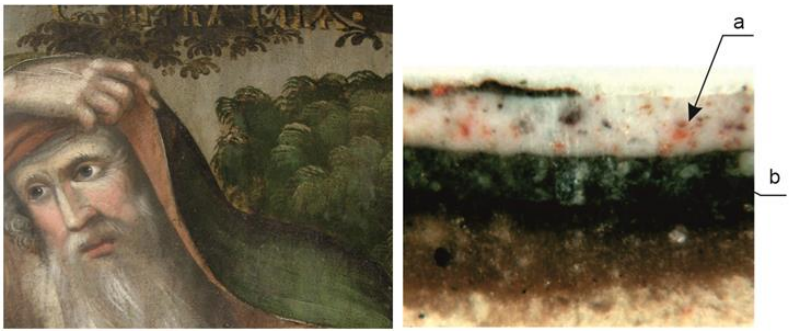

Fig. 3. A fragment of the wall painting of the southern wall with the use of verdigris pigment (a – lead bleach, ocher, b – lead bleach, green copper pigment verdigris)

A detailed visual examination of the painted surface of the interiors of the Trinity Church *in situ* shows that the plaster layer is applied to the uneven masonry of the wall. Longitudinal furrows with vertical and diagonal grains of sand are noted on the surface, characteristic of the manual method of applying the layer. A thin glue-chalk layer of claircole is applied on top of the 1 mm thick grout. The preparatory drawing or sketch is not visually visible. The formation of the volume of the faces was carried out by applying thin layers of paint with loads on the light areas in the form of a dense layer of lead white with ocher and red pigment. Executed with pasty strokes without clear boundaries that gently overlap each other in form, the painting of faces is characterized by the use of white in the shadows (Figs. 4, 5). There is some difference in the manner of execution of individual parts of the paintings, in particular, faces and clothes, which confirms the fact of the work of different artists. Each face is painted individually, defining the features of the personal "handwriting" of the master. Thus, one master is characterized by decorativeness and conventionality characteristic of icon painting, another is distinguished by a sense of colour and a characteristic feature of the third's manner is a detailed drawing. A defining feature for all of them is skillfully written details, which, at the same time, do not create the effect of oversaturation, but are harmoniously organized in compositions. At the same time, the construction of a pictorial surface, a kind of soft sculpting of the shape of faces and hands with the use of cold chiaroscuro and delicate undertones is characteristic of the period of the 18th century. The sophisticated execution of the faces emphasizes in places a more planar, decorative solution to the outfit. The pastose technique of painting depicts clothing folds with thick brushstrokes, combined with delicate glazing. The luxurious outfit, embroidered with pearls, with a variety of patterns, made by the method of applying gold and silver powder with the help of a fine brush, imitates rich and exquisite embroidery.

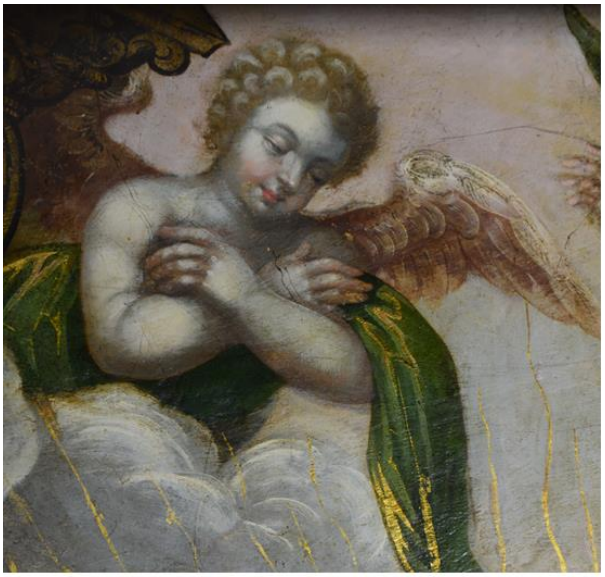

Fig. 4. A fragment of the painting of the central part of the altar. Photo by V. Zaitseva

A special place is occupied by the technology of landscape painting. Landscape compositions with a kind of symbolic content, smoothly flowing from one wall of the church to another, generously decorating them and leaving no free space, are made in a saturated gamut with a wide spectrum of green colour. According to the chemical-technological analysis of the samples, the optical effect of the depth of the image and the complex green colour was achieved by applying layers of blue smalt with lead white, on top of which a verdigris glazing was

applied on an egg white binder and a layer of varnish. It is quite interesting to write some details of the landscape. In particular, the characteristic rendering of tree leaves can be traced – with small textured strokes applied, probably with a special brush in the form of a fan.

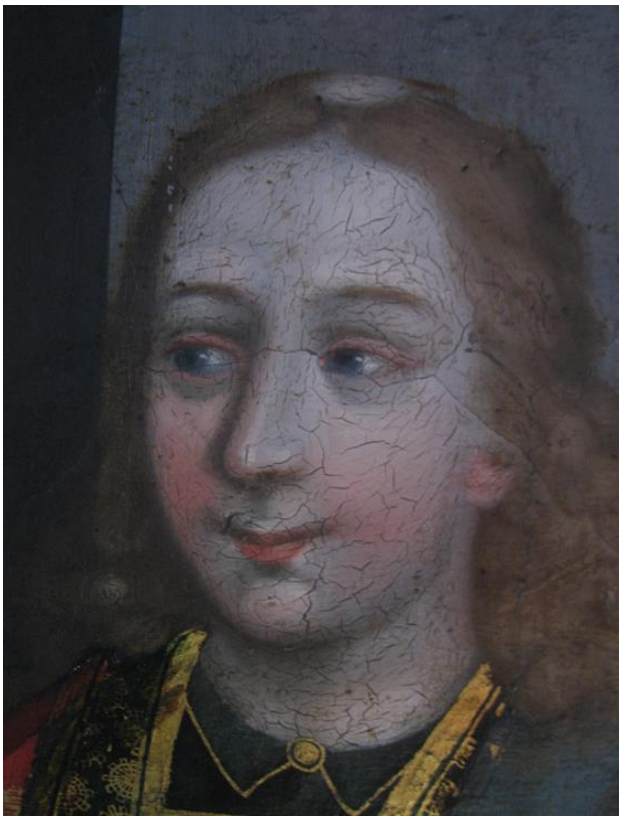

Fig. 5. A fragment of the painting of the central part of the altar. Photo by V. Zaitseva

Separate areas of the background are solved in the monochrome "grisaille" technique. Since the Middle Ages, this technique has been widely used in easel painting. In wall paintings, it was most often used to depict sculptural reliefs, usually acting as separate compositions. However, in the paintings of the Trinity Church, monochrome decorative and sculptural elements – columns, rosettes and ornamental compositions, made in the grisaille technique, are harmoniously combined with subjects solved in colour. At the same time, the imitation of rich molding creates the effect of expanding the space, connecting the interior with the juicy molding of the exterior, thereby "dissolving" the walls of a small church.

Thus, the analysis of the main palette and set of pigments of the paint layer of the wall painting gives reasons to assert the conformity of the painting of the Trinity Gate Church with the artistic traditions of European painting of the Baroque era.

Study of the ensemble of external wall paintings of the Trinity Church

The painting on the facades of the Trinity Gate Church was occasionally mentioned in scientific works and monographs only in the context of the study of the interior wall painting of the church. The propensity of external paintings to destruction under the influence of atmospheric factors and therefore frequent renewals and restoration measures, made their study difficult. Meanwhile, the external decoration of buildings with paintings has very old traditions, the origins of which go back to the 7th – 6th centuries BC from the decoration of Hellenistic

tombs. The appearance of external decoration of temple architecture in our region is associated with the influence of the art of the Balkans, Serbia and Moldova of the 16th and 17th centuries. However, recent research has somewhat changed this opinion.

It is customary to date the external painting of the Trinity Gate Church to the 40s of the 18th centuries. However, painting on the facades of the temple could have existed earlier. In particular, some information about the artistic-decorative and construction-technological features of the Lavra monuments was provided by the archaeological material discovered during the excavations of the Assumption Cathedral in 1982–1986. Thus, fragments of the plaster layer with the remains of the painting, which survived after the explosion, confirm the existence of external paintings on the facades of the Great Church dating back to the 15th–16th centuries. So, the external design could be on the Trinity Church.

The painting on the facades of the Trinity Gate Church, which is an image of saints, monks and scenes from the Holy Scriptures and hagiographies, can be conditionally divided into two groups. The first group consists of paintings made on plaster – the most traditional method of painting (crown pediments, upper register of facades, window slopes and acroteria of the eastern facade), the second – on metal plates with vertical placement on the areas of curtain walls and pilasters of the walls of the western and eastern facades, which were also often used as a basis for painting.

According to the results of chemical and technological research in 1976, the painting of the second group was made on a zinc base. Moreover, all the lower images are made on solid sheets of zinc, the upper ones are made on sheets riveted from two parts. Metal sheets are attached to the wall using forged nails with rounded heads. According to chemical and technological studies, the painting was done in several steps on a layer of red lead on an oil binder. The conclusions of laboratory research are confirmed by archival documents from 1899, according to which the author of the paintings, the artist Volodymyr Sonin, had to impregnate the base with "hot boiled oil to full saturation and cover it with red lead with Sannikov's bleach twice" [31]. This ground coat was chosen by V. Sonin not by chance, knowing the anti-corrosion qualities of red lead. Then, as a preparation, a layer of lead white is applied, directly to which the painting is done. Research in 1976 established that the paint layer is oily, dense and textured, with the use of white even in the shadows, the covering layer is applied in an even dense layer and it is difficult to remove.

The palette of used pigments is dominated by earthy yellow and brown colors. It is possible that the overall color of the painting changed over time – it became warmer. This could be due to a decrease in the refractive index of the binding oil paint, which is characteristic of painting done on tinted or dark grounds. The soil, which began to shine over time, seems to "eat" the greenish and other cold shades of the paint layer and becomes the cause of an increase in the contrast of light and shadow, which was not foreseen by the author. In addition, red lead, like all lead paints, turns black under the influence of hydrogen sulfide. In those places where the old oil soil was not preserved, the addition of painting was performed directly on metal.

According to the results of surveys in 1985 by specialists of the state institute "Ukrproektrestavratsiia", the background of the facades of the church, free from painting, was repeatedly repainted. Microchemical analysis of samples taken from the eaves of the first tier of the western facade revealed nine layers of paint: the original layer of the eaves – yellow, the background – blue and green layers [31].

Thus, based on the analysis of the technical and technological features of the ensemble of paintings of the Trinity Gate Church, as an integral component of its comprehensive study, the characteristic technical techniques and the specificity of the painting's manner of execution were determined [29]. Using the methods of microchemical, thermochemical, luminescence and emission spectral analysis, results were obtained regarding the composition of the materials of the monumental painting, which, of course, is of great importance in the study of Ukrainian artistic heritage.

The current state and factors affecting the preservation of the wall painting of the Trinity Gate Church

In July – September 2001, regular work on the facades of the Trinity Church was carried out by specialists of the Kyiv City Specialized Scientific and Restoration Project and Production Department. During this period, the walls and plinth were cleaned of layers, the plaster was restored, the walls were painted with lime and the window frames were cleaned and painted. The restoration program included a traditional list of measures, which included fixing the paint layer on the areas of destruction with a wax-lacquer composition, removing compacted contamination and the remains of the coating layer from the surface, removing and stabilizing metal corrosion products, puttying (using PF (pentaphthalium) putty compound) and toning losses [29].

In June 2001, based on a preliminary survey of the technical condition, the specialists of "Ukrproektrestavratsiia" developed "Design technological solutions for normalizing the moisture condition of the walls with paintings adjacent to the Trinity Gate Church". They provided for the performance of two main types of work: the installation of horizontal anti-capillary waterproofing and vertical waterproofing of the walls, the implementation of which would ensure the protection of the masonry from capillary suction of moisture from the soil adjacent to the walls.

Similar scientific and technological research was carried out in 2007 by the State Scientific and Technological Center for the Conservation and Restoration of Monuments (SSTC "Konrest") and provided recommendations on the technology of priority works to normalize the moisture condition of the masonry and determine the causes of the destruction of the painting and plaster of the Monastery walls and Trinity Gate Church.

During the scientific survey in 2007, the destruction of bricks and mortar (up to 3.0–5.0 cm deep in places) due to overwetting and weathering was noted in places where the plaster coating was lost. Research has determined that the thickness of the walls is 2.5–3 m on average. In the sections of the wall with paintings, the humidity exceeded the permissible limits for the satisfactory preservation of oil paintings. At a height of 2 m or more, the humidity tended to decrease. The humidity indicators determined as a result of the study significantly exceeded the maximum permissible norm.

Thus, the main causes of jamming were determined to be atmospheric precipitation and absorption of moisture from the soil at the capillary level, inadequate drainage of moisture from the adjacent territory and the walls in the absence of waterproofing of walls and foundations. In addition, gas emissions from motor vehicles, artificial soil salinity, vibrations and anthropogenic factors (improper repairs and restoration of the monument) and biological factors.

According to the project, in 2007, a complex of works related to the waterproofing of the wall on the northern side of the walls and the restoration of the painting of both compositions using traditional methods was completed.

In 2011, in connection with the need to develop scientific and project documentation for the next restoration work on the Trinity Gate Church, comprehensive studies of the technical condition of the external equipment of the monument – elements of masonry and decoration of facades were carried out (Figs. 6 and 7). The purpose of the research was to establish the degree of preservation of building and finishing materials, to determine their qualitative and quantitative composition and the peculiarities of construction technology for the development of the technology of further restoration. Samples of building and finishing materials were selected for laboratory (technological, microchemical, microbiological) research. In addition, a preliminary diagnosis of the moisture condition of the masonry and foundations was carried out in the areas available for measurements, as well as a description of the characteristics of the

distribution of moisture in the masonry along the perimeter and height of the building and the determination of the causes and sources of moisture.

According to the conclusions of the conducted research, it was determined that due to the lack of waterproofing of the foundations and the landscaping of the territory, the soils adjacent to the walls and foundations of the church are oversaturated with moisture, while the moisture content of the masonry reached 13–14%. Despite this, the condition of foundation masonry materials (construction mortar, plinth, brick and stone) was satisfactory and no significant destructive processes were detected. However, the basement part of the building and the protruding architectural elements of the facades, in particular, cornices, were in an unsatisfactory condition.

According to the results of the research, the cladding of the facades, which is an uneven layer with a thickness of 3 to 7 cm, has a different composition: lime and lime-gypsum of medium strength with a sand filler.

Fig. 6. Wall painting of the pediment of the western facade before restoration. Photo by V. Zaitseva

Fig. 7. Wall painting of the pediment of the western facade before restoration. Photo by V. Zaitseva

Available areas with cement content. The heterogeneity of plaster solutions is evidence of numerous repairs. Lime-glue (primary) paint layers and painting on various binders, including synthetic ones (a total of about 10 layers) were applied to the plaster [31]. The condition of the plaster layer was determined to be unsatisfactory: cracks, losses and peeling from the masonry. Weathering of masonry seams, destruction of bricks and other damages characteristic of wet masonry were observed in the areas where the plaster layer was lost. Biofouling was observed in some areas. As a result of laboratory studies, the main agents of bioaggression were identified – molds, as well as representatives of other groups of microorganisms – green and anticoccal algae, scale lichens, which were concentrated mainly in darkened and moistened areas.

Further complex research and repair and restoration works were recommended to be carried out in stages, with the provision of the necessary design and estimate documentation, which includes engineering and design studies (detailed examination of the roof and roof structures) and the formation of a thorough scientific and research base for further proper preservation and exploitation of the monument.

The main reasons for the emergency state of the stucco decor were related to the violation of its attachment to the wall, cracks, deformations of the walls, over-moistening and due to later layering [29]. The process of deep destruction of materials as a result of atmospheric precipitation and improper drainage provoked the development of microorganisms and further destruction. In addition, some architectural and decorative elements of the exterior were covered with a thick layer of pollution and bird waste products.

The lack of timely restoration, "natural aging" of materials, an aggressive environment and anthropogenic and technogenic factors led to the emergence of negative processes in the state of conservation of monumental painting and its base. Local destruction of the plaster layer and decorative elements of the facades of the monument in the form of losses, flaking and branched cracks was recorded. The connection of the paint layer and the soil with the base is broken and the presence of loss centres, flaking and severe deformation of the edges of the craquelure is revealed. As a result of the burning of the pigments of the author's painting and the darkening of the restoration tints and corrections, a general distortion of the colour of the monumental paintings was observed. At the same time, paintings on different bases have different degrees of preservation.

Sudden changes in temperature and humidity had a particularly detrimental effect on the condition of paintings made on a metal base. Wave-like deformations, general depletion and dents with local foci of metal corrosion are observed. Prolonged exposure to moisture and its sudden drying caused numerous losses and flaking on the entire surface of the images. The progressive dynamics of destruction in the form of the destruction of the binder and the shedding of pigments of the paint layer are enhanced by overwetting of the surface after precipitation. The percentage of surviving authentic paintings on separate images of the western and eastern facades does not exceed 20–25%.

Branched cracks and local losses of the plaster layer can be observed on the surface of the wall painting on the plaster base, especially in the upper part of the walls and in the areas of abutment with the metal roof of the gables (Fig. 8). There are cracks, flaking and loss of the paint layer with the soil in the areas of connection along the perimeter of the images on the metal base. Condensed pollution and soot from motor vehicle exhaust can be traced on the surface of the painting.

The issue of preservation and restoration of the wall paintings placed on the slopes of the fortress walls in front of the Trinity Gate Church has not lost its relevance. Significant changes in the state of monumental paintings are caused by both microclimatic, physico-chemical and natural factors, as well as the long-term lack of timely restoration. In both compositions, there are violations of the connection between the plaster layer and the masonry of the wall, as well as delamination of the plaster, which is especially noticeable in the lower

part of the images. The general deterioration of the condition is also caused by the activation and progressive nature of the destructive processes in the structure of the materials of the plaster and paint layer due to the direct influence of atmospheric factors on the mural area (overwetting, weathering, burning and degradation of pigments etc.).

Fig. 8. Destruction of the plaster layer on the gable section of the western facade. Photo by V. Zaitseva

On the surface of the painting, the decomposition of the varnish layer, compacted pollution, soo and a grid of hard craquelure with active peeling of the paint can be traced. The latest observations also record the progressive dynamics to the expansion of structural cracks both in the areas with paintings on the walls and in the interior of the Trinity Church. The situation is aggravated by the active movement of motor vehicles on Lavrska Street and the vibration caused by explosions during the shelling of the city in 2022–2023.

According to the results of the monitoring of the monumental paintings of the interior with an area of 720m², an unsatisfactory, locally dangerous condition is observed, mainly in the areas of the vaults, arches and the space under the dome, where there are structural cracks with peeling and loss of the plaster layer, as well as foci of damage by microflora (especially in stagnant zones). Areas with the removal of water-soluble salts, soot and compacted dust-fat pollution, which is a nutrient medium for the life of microorganisms, also pose a certain danger. As a result of the natural aging of the materials, the former restoration toning darkened, changed in colour and distorted the overall colour of the author's painting.

Thus, the following types of destruction of the ensemble of monumental paintings of the Trinity Gate Church have been determined:

1. Constructive (on cracks in the elements of architectural structures);
2. Structural nature (defoliation and loss of plaster base, paint layer, soil);
3. Damage to the surface by microflora (mold);
4. Mechanical damage caused by anthropogenic factors (scratches, chips, clothing friction).
5. Destruction of painting as a result of removal of water-soluble salts.
6. Darkening of former restoration tints.
7. Condensed dust pollution, soot and cobwebs.

Optimizing the restoration program of the Trinity Gate Church in the modern period

Experts have determined the following sequence of measures to be optimal for the restoration of the monument:

1. Identification of defects in structural elements, clarification of the causes of deformations, development of proposals for increasing the strength of foundations and architectural structures, development of a task for architectural restoration;

2. Elucidation of the causes of moisture in architectural structures, development and implementation of a project to protect the building from soil and surface moisture (waterproofing);

3. Elimination of the causes of precipitation of walls and vaults, modernization of the water drainage system from the roof;

4. Technical-technological and microbiological research of external and internal equipment, monumental painting, iconostasis;

5. Repair and restoration work on facades (repair of the roof, finishing works, restoration of stucco decoration, painting, gilding etc.);

6. Organization of observations under the temperature-humidity regime, study of internal air exchange;

7. Conservation and restoration measures on monumental paintings and iconostasis;

8. Development of building ventilation techniques and their implementation with the determination of the optimal operating mode.

The implementation of the restoration program of the monument of national importance "Trinity Gate Church" was undertaken by the "Creative Architectural Workshop "Y. Lositskyi". In 2018, preparations for repair and restoration work on the facades of the church began.

Currently, the current state of the church's exterior paintings has posed many difficult tasks for restoration artists. The main questions were mainly focused on the problem of reproduction of paintings on a metal base, which suffered significant losses of the paint layer, especially on the western facade. Taking into account the satisfactory condition of the metal base, the presence of the remains of the author's soil, paint layer and drawing, based on historical-archival, bibliographic searches, technical-technological and natural studies, the authors of the project – architect-restorer Nina Shepitko and specialists of Alla Yarosh Art Workshop LLC it was proposed to restore individual images on a metal base with the reconstruction of lost painting elements. As for icon images, where fragments of the original author's painting remain, ensure maximum protection and preservation of authentic areas with the possibility of exhibiting them [29].

At the same time, the idea of reconstruction of the lost painting was formed against the background of sharp professional disputes. Given the unsatisfactory condition of the murals, opposed proposals were put forward to solve the problem.

After a long controversy, at the meeting of the Scientific and Restoration Council of the National Kyiv-Pechersk Historical and Cultural Reserve in February 2019, the "Concept and rationale for painting restoration and restoration of the lost painting layer of icon images on the western and eastern facades of the Trinity Gate Church" was approved. The principle of restoring the integrity of the architectural and artistic image of the monument, guided by scientifically based methods, was taken as the basis of the idea of restoring the ensemble of exterior paintings of the Trinity Gate Church. Thus, based on the conclusions of comprehensive research, specialists have drawn up an optimal program for the restoration of the exterior and interior murals of the monument.

In the summer of 2019, restoration work began on the upper parts of the building, namely on the dome, in the lantern of which there were eight iconic images – "The Virgin and Child" and the holy archangels Jehudiel, Raphael, Gabriel, Seraphiel, Michael, Ouriel and Varachiel. The images were made on an iron base with oil paints. However, the state of preservation of the painting and the metal sheets of the base was so damaged that it made their

further preservation and exposure impossible: tears, losses, deformation, foci of metal corrosion and continuous shedding of the paint layer. The image was almost invisible. In this regard, it was decided to make new icons in the technique of oil painting on a new metal base, using the contours of old images. The dismantled images were moved to the reserves of the Reserve for further research and preservation.

Subsequent works required the restoration artists to solve many other problematic issues. In particular, in the process of removing later layering, some inconsistencies with the author's program of painting the exterior of the monument, which was approved by the Spiritual Cathedral of the Lavra and brought to life by the artist V. Sonin in 1902, were discovered. As analytical studies have shown, changes were made to the elements of individual icons, particularly inscriptions, during previous restoration interventions.

Certain difficulties also arose during the restoration of the wall painting on a plaster base, in particular, in the process of removing the covering layer and later toning and editing. The use of experimental varnishes and solvents based on synthetic resins during the previous works caused the formation of a cloudy film layer on the surface of the painting, which was difficult to remove. At the same time, the technology for removing the darkened tints that appeared everywhere in the author's painting required an individual selection of chemical solvents for individual areas of the painting and considerable experience in complex work.

In the fall of 2021, restoration work on the western facade of the Trinity Gate Church was completed. In addition, the roof was repaired and replaced, the stucco decoration of the western, northern and southern facades and the drum of the dome were restored and gilded works and walls were painted. Further measures were related to the organization of conservation and restoration works on the eastern facade, as well as in the interior of the Trinity Gate Church. In 2022, the restoration work was suspended due to the Russian military invasion of Ukraine.

As already noted, an important factor that determines the state of works of monumental painting of architectural objects is the temperature and humidity regime, which slows down or stimulates physicochemical, physico-mechanical and biological processes. Day-to-day observations of the relative humidity of the air in the interior of the Trinity Gate Church, which were carried out with portable thermo-hydrometers, recorded fluctuations of up to 5 – 7% with a permissible 1 – 2%.

One of the reasons for the violation of the temperature and humidity regime of the monument was the lack of sealing of the window openings in the vestibule and the main volume of the church. Due to the passage of moisture through the cracks, the wooden frames were destroyed. Losses, damage to internal painting and the development of mold fungi were visible on their surface. To organize heat and humidity conditions, it was proposed to replace the window frames in the interior of the monument, which in turn made it possible to reduce the period of low air temperature below 0ºC. A certain stabilization of internal parameters of temperature and humidity made it possible not only to organize the restoration process in the interior but also to determine the further operation of the monument.

Today, the entire scientific and analytical arsenal is based on the restoration project of the architectural monument of national significance "Trinity Gate Church", which includes: the accumulation and documentation of historical information about the monument during its existence; identification of periods, volumes and quality of previous historical layers, renovations, restoration interventions; understanding the authenticity and value criteria of a work of art, taking into account artistic traditions and worldview; study and analysis of the material component (technical and technological research); research and diagnosis of the state of preservation.

Common problems of preservation of wall paintings in different countries

Despite the differences in the styles of wall paintings, the preparation of the foundations for wall painting, the techniques of wall painting and the applied artistic materials, the problems

of their preservation are common in many countries, which is visible when comparing the destruction of the wall paintings of the Trinity Church and the Buddhist wall paintings of the Dunhuang shrines in China. At first glance, there are fundamental differences between them: the mural of the Trinity Church was made based on brickwork from above and the mural of Dunhuang was based on the stone surfaces of natural caves from above, in addition, different methods of making wall paintings were used and different styles determined by beliefs (Buddhism and Christianity), chronology and cultural traditions.

However, the causes of the emergency state are common. The main problem of the Dunhuang wall painting is also the change in microclimate and excessive humidity. Just as in the case of the Trinity Gate Church, in the case of Dunhuang's wall paintings, paints based on mineral pigments were used, which were characterized by color saturation and long-term colour retention [30].

The use of paints with such a chemical composition formed a specific genre of wall painting "Zhòngcǎi hua" ("Saturated color paintings"), which ended its existence in the Yuan period - the last period of the formation of the Dunhuang complex. Painting in the "Gōngbǐ zhòngcǎi" ("Meticulous and colorful") technique was also formed based on mineral pigments (cinnabar, azurite, malachite, gold and white powder). The prevalence of such techniques turned out to be so great that the traditions of using wall painting techniques with paints based on mineral pigments were used until the appearance of Western painting techniques in the Qing period.

Each of the dynasties formed its own methods of applying paints [30,32,33]. For example, in the early period of the Wei dynasty, the colour of laterite was predominant, the basic color for the general background was white, on which other colors were superimposed. In the middle period of the Tang dynasty, the use of metal foil added to the effects.

Studying the frescoes of the Dunhuang shrines by modern methods includes the methods of stereomicroscopy, ultra-deep-field microscopy, X-ray diffraction, electron microscopy, spectroscopy and the Frontier method. Organic (acrylic polymers Parrot B-72 and AC33) and inorganic materials (lime water, barium hydroxide, alkaline earth silicate) are widely used as reinforcing materials. As a progressive new method, a method of strengthening and protecting murals with graphene-based nanomaterials is proposed.

Conclusions

Based on the analysis of selected samples of structural materials of the painting of the Trinity Church, the following conclusions were drawn [29].

The walls of the Trinity Church are made of red brick and wild stone. The frescoes of the interior of the Trinity Gate Church were executed no later than 1734 in the technique of oil painting (the main group of pigments: white lead, smalt, verdigris, orpiment, red lead, ochre, umber, ultramarine, indigo, cinnabar). A 2-3 cm thick plaster layer of the 16th–17th centuries was used as the basis for the painting, which contained identified lime with a filler (sand) and vegetable glue, on which the remains of the original painting were preserved. The original painting, made with glue paints, can be dated to the beginning of the 17th century (preserved fragmentarily, in unsatisfactory condition) and needs additional research.

Exterior painting made on a metal base. The base material is zinc. Painting in the oil painting technique is done on a layer of oily soil containing red lead.

According to the conclusions of the conducted technological studies and modern scientific monitoring of the Trinity Overgate Church, the problems of the current state of the monument were determined and a program of necessary conservation and restoration measures was developed. One of the most important principles of scientific restoration is the basis of the provisions of the modern restoration program of the Trinity Gate Church – the principle of

minimal intervention in historical material, which corresponds to international monument protection documents ratified by Ukraine.

The relevance of this principle today is directly related to the development of science and technology, as well as the use of modern materials and technologies in solving the problem of ensuring the protection of paintings from external climatic influences, taking into account the duration of preservation of their exhibition appearance. Therefore, the issue of the durability of applied restoration materials for the preservation of the already restored painting becomes of significant importance. In addition, the main principles and methods of restoration, the choice of materials for the conservation of outdoor painting, which is under the influence of solar radiation and aggressive impurities in the air of a modern city, should be aimed at ensuring the conditions for preserving the authenticity of its material structure, as well as its artistic and historical significance.

As a result of the study of the current state of the monumental painting of the Trinity Gate Church, thanks to modern comprehensive research and the conclusions of scientific monitoring of the monument in recent years, it was established that the fact of the lack of timely restoration, "natural aging" of materials, aggressive environment, anthropogenic and technogenic factors led to the occurrence of negative processes in the state of conservation of paintings (structural cracks, destruction and deformation of the base, loss and peeling of the paint layer and soil, craquelure, degradation of pigments, biodamage, pollution).

It has been proven that the main factor affecting the preservation of wall paintings and icon paintings is changes in microclimatic conditions in the interior of the temple.

The common problems of the state of emergency for wall paintings of different countries have been determined, in particular, by studying the wall paintings of the Trinity Church and the Dunhuang sanctuaries, it has been established that the main cause of damage and loss of painting fragments based on mineral paints is a change in microclimate and excessive humidity.

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