INTERNATIONAL JOURNAL
OF
CONSERVATION SCIENCE

ISSN: 2067-533X Volume 15, Issue 3, 2024: 1389-1406 www.ijcs.ro

DOI: 10.36868/IJCS.2024.03.15

CERTAIN ASPECTS OF RESEARCH WORK IN THE RESTORATION OF THE KYIV VELODROME

Oleksandr MOLODID[1*], Volodymyr SKOCHKO[1], Sergey BOGDAN[2], Marek PABICH[3], Karol WYSZNACKI[3], Joanna BOROWCZYK[3]

[1] Kyiv National University of Construction and Architecture, 31 Povitroflotskyi Avenue, Kyiv, 03037, Ukraine
[2] LLC "Mapei Ukraine", 13 Yevhena Sverstiuka Street, 5th floor, Kyiv, 02002, Ukraine
[3]Lodz University of Technology, Institute of Architecture and Urban Planning, 116 Zeromskiego Street, Lodz, 90-924, Poland

Abstract

Kyiv Velodrome is the oldest sports facility in Ukraine and one of the oldest in Europe. In 2016-2017, the restoration of its track, administrative building, construction of an underground parking lot and reorganization of the adjacent territory were carried out. As part of the scientific and technical support, an examination of the velodrome track was carried out to determine all existing defects and damages and as a result, recommendations for their elimination were provided. In particular, solutions have been developed to repair cracks and recommended measures are aimed at preventing their appearance in the future. Also, within the scope of research work, some experimental studies were carried out with the designed constructions of the bicycle track for their compliance with the technical documentation and to establish durability (in laboratory conditions). The article analyzes and researches the structural and technological solutions proposed in the project documentation for the restoration and arrangement of the bicycle track, providing solutions and recommendations that will ensure the necessary quality and the project's design life. Thus, recommendations are being considered to reduce the likelihood of the appearance of new cracks and the development of existing ones on the track.

Keywords: *Repair; Velodrome; Velodrome track; Restoration work; Inspection; Crack; Damage; Track surface*

Introduction

Kyiv Velodrome is the oldest sports facility in Ukraine and one of the oldest in Europe [1]. The complex of buildings, which consisted of a bicycle track and a wooden pavilion [2] was erected in 1913 on the initiative of Kyivan I.P. Bilenko in the yard of Fundukleivska Street (now Bohdana Khmelnytskoho Street) [6], on the site of the Afanasiivskyi Ravine (Fig. 1), which was filled in at the end of the 19th century. Spring, rain and meltwater flowed through this ravine into the valley of the Lybid River. The velodrome was built in the central part of the filled ravine, in the floodplain of the Lybid River. Today, this is a block bounded by Bohdana Khmelnytskoho Street, Mykhaila Kotsiubynskoho Street, Viacheslava Lypynskoho Street and Ivana Franka Street in the Shevchenkivskyi district of Kyiv.

In 1912, I. Bilenko received permission to build a bicycle track and a wooden pavilion at 58 Fundukliivska st. (now Bohdana Khmelnytskoho st.) from the vice-governor and the city architect of that time, Oleksandr Kryvosheiev. According to the resolution, I. Bilenko was given

* Corresponding author: molodid2005@ukr.net

the opportunity to equip a bicycle track with a wooden shed according to the project provided under the following conditions:

- mandatory installation of two fire hydrants;
- that the electric lighting wires be in copper tubes;
- that the construction of the track and the pavilion be reported to the construction department [2].

Unfortunately, no photo of the Kyiv cycle track as it looked in 1913 hasn't been preserved.

The construction of the velodrome lasted about a year and was completed on the eve of the Sports Olympics in Kyiv, which took place from August 20 to 28, 1913 [2].

Fig. 1. Afanasiivskyi Ravine at the beginning of the 20th century [2]

The festive opening of the newly built sports facility took place in 1913 and was dedicated to the 300th anniversary of the House of Romanovs [6]. At the beginning of its operation, the rental and repair of bicycles, motorcycles and cars was organized there. The Polar Star Summer Theatre with an orchestra was located near the velodrome. In tsarist times, a cinema was also located here [1]. In general, at the beginning of its operation, the velodrome became not only a sports facility but also a place of cultural recreation for Kyiv residents and city guests.

In Soviet times, the velodrome was actively used exclusively as a sports facility. It functioned only as a training base for athletes and a place for holding official competitions. In different periods, the Kyiv Velodrome served as a base where 39 world champions, 20 world championship medalists, Olympic champions and Olympic Games medalists of various years honed their sportsmanship [1] (Fig. 2).

In 1939, the first repair was carried out – the ground surface was replaced with asphalt, a new fence was installed and the entrance from Lenina Street (now Bohdana Khmelnytskoho Street) was arranged. Considerable attention was also paid to the arrangement of the tribunes [2]. During the Second World War, the velodrome was practically undamaged, so after the end of the war, it resumed its work.

The next significant repair works at the Kyiv Velodrome were timed to the 1980 Summer Olympics. So, in 1978 –1980, the concrete track surface was replaced with wooden and the spectator stands were restored. The repair and restoration works made it possible to increase the maximum speed on the track to 85km/h and the number of spectator seats was increased to 5,000 [2]. However, the cycling track was not covered, so it was constantly exposed to atmospheric precipitation. This led to the gradual deterioration of the wooden surface. So, in 10 years (in

1991), the Kyiv Velodrome was waiting for a new reconstruction. According to its results, the wooden coating was replaced with a new concrete coating with polymer additives [1, 2, 6].

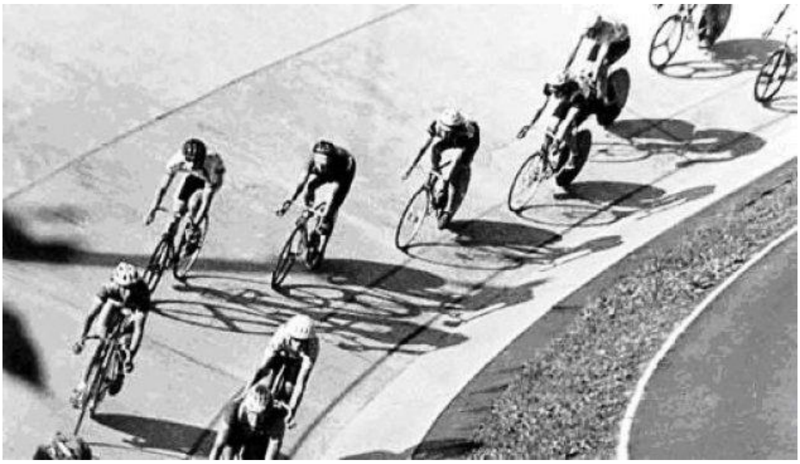


Fig. 2. Holding competitions on the Kyiv Velodrome in Soviet times [2]

In the first years of Ukraine's independence, the Kyiv Velodrome continued to operate. There were trainings, competitions and a sports school [1]. Taking into account the uniqueness of the building and its age, at the request of the Department for the Protection of Monuments of the City of Kyiv, the Kyiv Velodrome was declared a monument of history and architecture by the Kyiv City State Administration in 1998.

In 2004, the last official competitions were held before the closure of the sports facility and the start of full-scale construction work. However, in 2007, the building was deprived of its protective status, having been deemed unfit for further use [2]. On March 20, 2009, the velodrome began to be demolished due to the construction of a 4-section, 20-story residential building, which surrounds the velodrome on one side and is less than 1 m away. Fortunately, thanks to loud publicity among the public and Mass media managed to stop the new construction. But the dilapidated velodrome has turned into an abandoned wasteland and garbage dump. Over time, it was overgrown with trees and grass and the walls were painted with hundreds of graffiti [1, 2] (Fig. 3).

Fig. 3. View of Kyiv Velodrome before restoration [2]

Lance Armstrong's photo, which he posted on his Twitter in 2014 [1] (Fig. 4), served as one of the impetuses for the restoration of the Kyiv Velodrome. In 2014, the velodrome began to be restored, garbage was removed from it and the corner sector (which was destroyed in 2009) was restored. This became a new page in the history of the building. In October 2014, according to the order of the Ministry of Culture of Ukraine No. 869, the Kyiv Velodrome again received the status of an architectural monument.

Fig. 4. Lance Armstrong in the uniform of the National Team of Ukraine rides the destroyed Kyiv Velodrome in 2014 [1]

In 2016, the restoration of the track surface, the administrative building, the construction of an underground parking lot and the reorganization of the adjacent territory began. In 2017, the residents of Kyiv saw an updated bicycle track, which is considered one of the best in Europe. The cost of its reconstruction amounted to UAH 96 million. The view of the Kyiv Velodrome is shown in Fig. 5.

Fig. 5. View of Kyiv Velodrome after restoration in 2017. [Source: https://apostrophe.ua/]

During the restoration works in 2016-2017, the following works were performed on the Kyiv cycle track [3]:

- installation of a modern sports surface produced by the well-known Italian company MAPEI;
- the administrative and sports building was reconstructed with the arrangement of premises to meet the needs of athletes (locker rooms, showers, a first aid post, a gym and a cycling studio, a repair shop and bicycle storage boxes, etc);
- installed the grandstands for 280 spectators;

- administrative premises were arranged;
- an underground parking lot for 40 cars, a public restroom and a cafeteria were built on the undeveloped land plot between the cycle track and the park;
- the territory of the cycle track was freed from the heating networks that used to run there in the open, now they are laid along Lypynskoho Street and made energy-saving;
- the area around the bicycle track was landscaped, a joint public space with O. Honchar Park was created with landscaping, restoration of the retaining wall along V. Lypynskoho Street, and provision of outdoor lighting for the bicycle track and the surrounding area.

The renovated cycle track has become one of the best in Europe. The main characteristics of the track design [4]:

- length of the bike path - 285.714 m
- width on bends - 8 m
- maximum inclination angle - 38;
- transverse angle in a straight line - 11;
- length of the transition curve - 21.5 m;
- constant bend radius - 21.7 m;
- permissible speed - 73.58 km/h;
- capacity of the stands - 2,000 spectators.

During the repair work, the cycle path was restored, new concrete was poured, and a topcoat was applied. Later, the track was marked and a screen was installed to broadcast the races and display information about the course of the competition. In the center of the bend, a new lawn and a ramp for performing tricks were laid, and a running track was built around it. Several pathes with different surfaces were laid around the perimeter. The largest one is 285.7 meters long. As noted above, the reconstruction included renovation of the stands and installation of benches above the bend [5].

Since its opening, the Velotrack has become a center of cultural and sports life. The cycle track regularly hosts events to promote cycling and cycling culture, including meetings with famous athletes and personalities, master classes from famous athletes and sports stars, photo exhibitions, events of the Kyiv Cyclists Association, MotoHelp trainings on emergency medical care in case of an accident, seminars on the rules of safe cycling in the city, exhibitions and competitions of vintage bicycles, meetings of sports clubs, etc.

It has become a good tradition to set records on the cycle track, which attract a lot of public and media attention. In particular, in addition to purely sporting records (set at ranking competitions), three hourly track records and 100-kilometer records (for men and women), a world record for the distance of riding an electric bike (included in the Guinness Book of Records), and an hourly record on a vintage bike were set after the reconstruction.

The head of the Kyiv Velotrack outlined the strategic goals of the institution for the coming years. These are the functioning of the cycle track as the Center of Cycling Culture in Kyiv, on the basis of which to develop urban sports and social cycling projects (sports schools, clubs, sections, public initiatives); renewal of children's and youth's interest in cycling; development of cycling infrastructure as a place for active leisure; development of the cycle track as a high-level multifunctional sports center [3].

The protection and preservation of the Kyiv Velodrome require additional attention in the conditions of military operations and massive shelling of Ukraine by the Russian Federation. The issue of cultural heritage protection in the conditions of military operations is extremely relevant and urgent [7, 8]. Historical buildings and architectural monuments require immediate measures aimed at restoring and preserving the historical heritage for posterity.

By the Law of Ukraine "On the Protection of Cultural Heritage" [9], the following types of work are allowed on cultural heritage objects: conservation, restoration, rehabilitation, museumification, repair and adaptation of monuments with the permission of the relevant cultural heritage body based on an agreement with it scientific project documentation.

The scientific novelty of the obtained results lies in the substantiation of the method of restoring the Kyiv cycle track, which is an architectural monument and one of the oldest such sports facilities. Thus, in laboratory conditions, the effectiveness of various design and technological solutions under possible operating conditions was investigated, the best ones were selected, and recommendations for their improvement were provided. Therefore, the results obtained can be used in restoration work or new construction at similar or similar facilities.

Matherials and Methods

In the course of research, the authors used the following general scientific methods: visual – when determining the technical condition of structures based on external features; analytical – when assessing the technical condition of the inspected object, instrumental – when studying the physical and mechanical indicators of structures; experimental – for conducting research in laboratory conditions to establish the strength indicators of structures.

Under the purpose of the study, the following sources were used:

1) normative legislative framework [7, 9, 11, 12];

2) the issue of preservation of historical and cultural heritage [7 – 9, 16, 19];

3) issues related to the technologies of restoration of operational suitability [11 – 15, 17, 18];

4) issues related to systematization of damages [10]

5) Issues related to the preservation and restoration of buildings and structures [19 – 23, 25, 26].

The study of the normative legislative framework and the state of historical and cultural buildings and sports facilities that need restoration became the theoretical basis for studying the studied sources and providing recommendations for restoring the operational suitability of sports facilities that have architectural and historical value.

The purpose of the work is to analyze and investigate the constructive and technological solutions proposed in the project documentation for the restoration and arrangement of the bicycle track fabric and to provide solutions and recommendations that will ensure the required quality and the design life of the project.

Since the experience of restoration work at similar facilities is limited, in order to prevent possible errors in the design and execution of the relevant work, it is necessary to perform a comprehensive study and research of possible design and technological solutions. In our opinion, one of the best methods in such cases is to conduct experimental studies with modeling of conditions that will be as close as possible to real operating conditions. Such studies should be based on specially developed methods and plans for experimental research. The proposed methods and the results obtained can be used in restoration work or new construction at similar or similar facilities.

Results and Discussion

With the participation of the authors in 2016 – 2017, as part of scientific and technical support works at the facility: "Restoration with adaptation for the modern use of the velodrome at 58 Bohdana Khmelnytskoho Street and improvement of the territory within the boundaries of Bohdana Khmelnytskoho, Mykhaila Kotsiubynskoho and Viacheslava Lypinskoho streets in the Shevchenkivskyi district of the city of Kyiv" [27] provided for the development of recommendations for carrying out repair work on the existing surface and research of the designed structure of the velodrome track for durability. Scientific and technical support was performed by specialists of the State Enterprise "Research Institute of Construction Production" under the leadership of the responsible executor Oleksandr Molodid.

The conducted research and work carried out within the scope of scientific and technical support have scientific value and will be of interest both to subcontractors carrying out similar work and to scientists who develop scientifically based technical solutions at unique facilities.

First of all, the scientists performed a technical survey and analyzed the existing condition of the Kyiv Velodrome track. Thus, the bicycle track is located on bulk soils of a considerable thickness, there are also subsiding loess soils on part of the site.

At the time of carrying out a technical inspection in the area of the existing track, the base consisted of a dense crushed stone layer, under which there is a soil embankment that forms the slope of the bicycle track. The fabric existing at that time had three layers:

– the bottom layer – monolithic concrete of a dense structure with a thickness of 50 to 108mm;

– the middle layer – the finishing coating of the primary surface of the bicycle track made of cement-sand mortar reinforced with a mesh made of Bp-II (Vr-II) wire with a diameter of 5mm, a step of 100mm; layer thickness from 58 to 128mm;

– the upper layer – the finishing coating, arranged after the repair of the bicycle track in the 1990s, made of monolithic concrete, reinforced with a steel mesh of smooth reinforcement with a diameter of 8mm, a step of 200mm.

During the restoration works in 2016, the project documentation provided for the arrangement of new additional layers on top of the existing ones. The arrangement of the lower layers of repair cement mixtures will make it possible to level and form the necessary surface of the bicycle track. Applying the upper (finishing) layers of polymer materials will protect the bicycle track from the influence of external negative factors and provide the necessary surface properties to ensure the necessary contact of tires with it.

Prior to the start of the restoration work, a visual and instrumental survey of the existing bicycle track surface was performed, as a result of which a large number of cracks (Figs. 6 and 7), bumps and depressions were revealed. Insignificant depressions and humps were proposed to be closed during the installation of leveling layers, so additional actions for their elimination were not foreseen. Instead, the existing cracks had to be repaired.

As part of the scientific support of the object, recommendations were made to reduce the probability of the appearance of new cracks and the development of existing ones. The recommendations include the following: arrange temperature seams according to the recommendations of regulatory and technical literature; arrange a stormwater drainage system outside the cycle track and provide for drainage systems; limit the entry of heavy equipment onto the cycle track; ensure reliable protection of the concrete structures of the bicycle track from water by installing protective coatings.

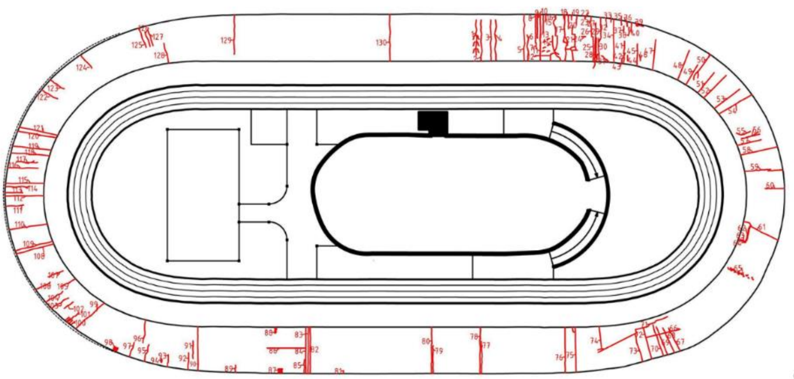


Fig. 6. Scheme of placing cracks on the bicycle track

Fig. 7. Cracks on the bicycle track

In addition, technological solutions were developed, which involved injecting cracks with high-flow epoxy glue. The permissible crack opening width, which can be considered insignificant, is 0.3mm. Such cracks are called *hairline cracks*. If the width of the crack is greater, moisture penetrates it. At sub-zero temperatures, water turns into ice and wedges the edges of the crack. This will occur with each cycle of freezing and thawing and lead to the destruction of concrete throughout the thickness of the slab. In addition, water through the crack enters the foundations of the soil under the slab and provokes its subsidence. To prevent such negative effects, even hairline cracks must be eliminated.

It is proposed to repair the cracks in the following technological sequence using TM "Mapei" materials [28]:

1) in the upper part of the crack (along its entire length), make a cut 5–6mm deep and 4–5mm wide (Fig. 8);

2) stick masking tape on both edges of the cut (so that the concrete surface is not contaminated with glue in the future);

3) thoroughly blow out the cut and crack with compressed air to remove the remains of concrete and dust;

4) use a syringe to fill the crack with pre-prepared epoxy glue "Epojet";

5) after 2–4 hours, use a syringe or spatula to fill the gap with epoxy-based glue "Epojet" with a filler (quartz sand), followed by leveling the mixture to the level of the concrete surface. Mix "Epojet" glue with sand in a ratio of 1:4 or 1:5;

6) after 10–30 minutes, sprinkle the surface of the last mixture with river sand.

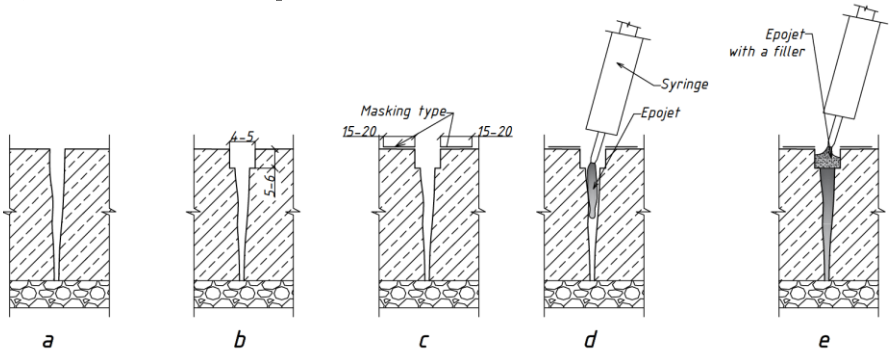


Fig. 8. Technological sequence of cracks repair with materials: a – existing crack in the concrete web; b – cutting of the crack in the upper part; c – sticking masking tape; d – epoxy-based glue "Epojet"; e – "Epojet" glue mixed with quartz sand

According to the program of scientific support for the cycle track, it was envisaged to study the designed structure of the bicycle track for durability (in laboratory conditions).

The designed bicycle track is a multi-layer structure consisting of materials that have different physical and mechanical properties. Each layer in this structure must perform its function and have a strong connection with each other. To investigate the individual physical and mechanical properties of the entire designed structure in laboratory conditions, it was decided to prepare samples for testing from sequentially applied layers of the bicycle track on the concrete structure.

The possibility of using one or several of the 4 possible design, structural and technological system solutions for the arrangement of the bicycle track was foreseen. All possible system solutions provide for the sequential application of layers of fabric on a base made of B25 concrete. These works are aimed at increasing the life cycle of the reconstructed object [24].

System solution No. 1: Adhesive layer Mapefloor I 910 (1–2mm); Nivoplan Plus + Planicrete (20–25mm); Adhesive layer Ceresit CD24+CC81 (2mm); Leveling layer Ceresit CD24+CC81 (20mm); Finishing layer (putty) Ceresit CD24 + CC81 (5mm; Primer Mapecoat I 600w (0.1–0.2mm); finishing coatings.

System solution #2: Mapecoat I 600w primer (0.1–0.2mm); Mapecoat TNS White Base Coat (up to 8mm); Adhesive layer Ceresit CD24+CC81 (2mm); Leveling layer Ceresit CD22 + CC81 (up to 40mm); Finish layer (putty) Ceresit CD24 + CC81 (up to 5mm); Primer Mapecoat I 600w (0.1–0.2mm); finishing coatings.

System solution No. 3: Adhesive layer Mapefloor I 910 (1–2mm); Nivoplan Plus + Planicrete (20–25mm); Adhesive layer Ceresit CD24+CC81 (2mm); Leveling layer Ceresit CD24+CC81 (20mm); Finish layer (putty) Ceresit CD24 + CC81 (5mm); Primer Mapecoat I 600w (0.1–0.2mm); finishing coatings.

System solution No. 4: Adhesive layer Ceresit CD24+CC81 (2mm); Leveling layer Ceresit CD22+CC81 (up to 40mm); Finish layer (putty) Ceresit CD24 + CC81 (up to 5mm); Mapecoat I600w primer (0.1–0.2mm); finishing coatings.

In all four system solutions, the finishing coatings were arranged in the following sequence from the following materials: Mapecoat TNS White Base Coat (up to 0.8mm); Mapecoat TNS White Base Coat (re-application) up to 0.4mm; Mapecoat TNS Finish up to 0.4mm; Mapecoat TNS Finish (re-application) up to 0.4mm; Mapecoat TNS Paint 0.1mm; Mapecoat TNS Paint (re-application) 0.1mm; Mapecoat TNS Line 0.1mm; Mapecoat TNS Line (re-application) 0.1mm; Mapecoat TNS Protection 0.1mm; Mapecoat TNS Protection (re-application) 0.1mm.

The performance of laboratory experimental studies is provided on factory-made reinforced concrete lintels 1 PB 10-1 with the following characteristics: length x width x height – 1030 x 120 x 65mm; mass – 20kg; concrete class – B25. The class of concrete of the membrane corresponds to the class of concrete of the bicycle track.

Preparation of materials and application of coating layers were carried out following technological maps and technical instructions provided by the customer and manufacturers of building materials. The preparation of laboratory samples consisted of the step-by-step application of layers of material on the surface of concrete lintels. It was assumed that one of the system coating solutions would be applied to each lintel.

The layers of material applied to the lintels to the Mapecoat TNS system were arranged on the entire surface of the lintel (Fig. 9). The layers of materials that make up the TNS system are applied to only half of the membrane on the previously applied layers of the structure (Figs. 9 and 10). Such actions are provided for the purpose of the possibility of researching individual physical and mechanical indicators of coating structures before the installation of the protective finish coating composed of the TNS system and with its installation.

The work was performed at a temperature of 12–15ºC and a relative humidity of 55–60%. The temperature of the air in the room where the samples were kept was deliberately not increased for greater accuracy of simulation of natural conditions. After all, work on the restoration site was expected to be carried out in March – April. It is at this time that the average daily temperature is 5–12ºC.

Following regulatory documents, coatings made from mixtures on a cement binder were kept for 28 days in air-dry conditions before performing tests on them. According to the manufacturer's recommendations, the Mapecoat TNS system can be tested 7 days after applying the last layer.

The research program provides for establishing the adhesion strength of the coating layers to each other and the base without and with the Mapecoat TNS system. In addition, beams are cut from the coating to determine their bending strength and fragments of lintels formed after breaking are used to determine compressive strength.

The constructions of coatings on membranes were cut into samples for further tests using an angle grinder with a disc on concrete (Fig. 10). Cutting was performed to the full depth of the samples with a 5–7mm slit in the membrane structure.

a b

Fig. 9. Lintels for the study of the layers of the structures covering the bicycle track: a – lintels without coating; b –coated lintels

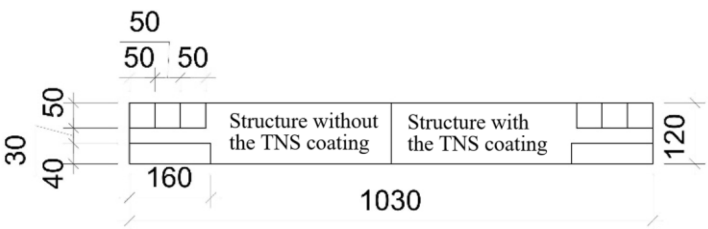


Fig. 10. The design of the coatings cut for testing

Thus, after cutting the coating, three fragments with dimensions of 50x50mm were obtained on two parts of each membrane and one beam with dimensions of 160x40mm. Lintels were cut from the membranes for further studies. After the planned experimental studies were carried out with the first batch of prepared samples, the fragments of the layers remaining on the lintels were tested for frost resistance.

Before the beginning of experimental studies on frost resistance, the lower and side surfaces of concrete lintels were covered with waterproof and salt-resistant coatings. This action was performed to exclude the possibility of water entering the body of concrete and samples through the side surfaces since water will enter the surface of the bicycle track only from above.

Determination of frost resistance of the samples was carried out according to the second accelerated method following the requirements of DSTU B V.2.7-239:2010 "Building materials.

Construction solutions. Test methods" and DSTU B V.2.7-49-96 "Building materials. Concretes. Accelerated methods of determining frost resistance during repeated freezing and thawing".

Before the test, the samples were saturated in a 5% NaCl aqueous solution at a temperature of 15–20ºC for 48 hours. After that, they were placed in the freezer on the mesh shelves of the racks and kept for 4 hours at a temperature of minus 18–20ºC. After unloading from the freezer, the samples were thawed in the same aqueous solution as before freezing for 3 hours at a temperature of 15–20ºC Alternate freezing and thawing of samples was performed 13 times, which corresponds to the basic method of testing for frost resistance – 75 cycles.

24 hours after the samples were extracted from the aqueous solution, they were cut into fragments to determine the adhesion strength of the layers and compressive strength.

First of all, the strength of adhesion to the base was determined after keeping the samples in air-dry conditions. The strength of adhesion of the layers to each other and the base was determined according to the method described in DSTU B EN 1015-12:2012 "Methods of testing mortar for masonry. Part 12. Determining the adhesion strength of plaster mortars to bases".

Bond strength is defined as the maximum tensile stress resulting from the action of a direct load perpendicular to the surface of the solution applied to the base. Tensile forces are applied with the help of a special tear-off plate, which is glued to the surface of the solution being tested. The resulting bond strength is the ratio of the destructive load to the area.

With the help of the test setup (Fig. 11), using tear-off plates, a tensile load was applied perpendicular to the tested area. The load was applied at a uniform speed, avoiding shocks. When tearing off a fragment, the device automatically records the effort and displays it on the screen.

Fig. 11. The process of determining the adhesion strength of structure layers

The average bond strength is calculated as the arithmetic mean of the bond strength of 3 samples with an accuracy of 0.1 N/mm^2. The results of the research are presented in Table 1.

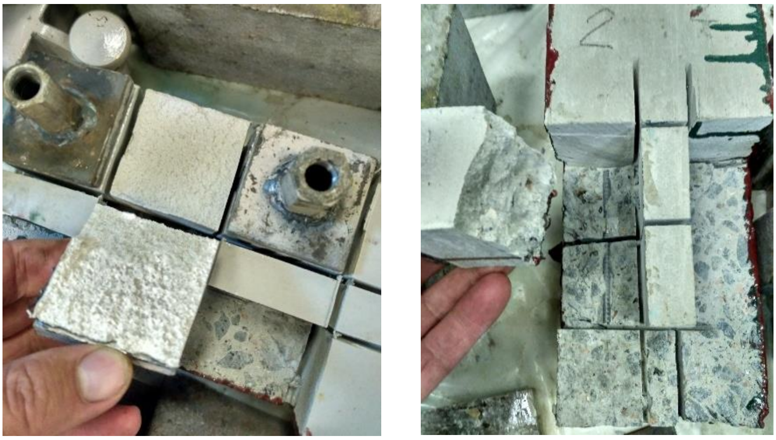
Characteristic types of breaks in the material of structures are shown in figure 12.

In the future, the adhesion strength of the layers of the samples to each other and the base was determined after testing them for frost resistance. The results of the research are presented in Table 2.

After determining the adhesion of the cut samples covered with the Mapecoat TNS system, the remaining protective layers were cleaned and adhesion plates were glued to the surface of the samples. This action was performed to establish the bond strength of leveling layers that were protected by the Mapecoat TNS system during frost resistance tests. The results of these studies are given in Table 3 and figure 13.

Table 1. The results of research on the strength of the adhesion of the layers of structures to each other and to the base.

The construction under study	Adhesion strength to the base, MPa		Notes
	normative (recommended by the manufacturer)	defined	
System solution #1			
Without the Mapecoat TNS system	not less than 2	2.2	separation on concrete
With the Mapecoat TNS system	not less than 0.5	0.2	separation from I 600w
System solution #2			
Without the Mapecoat TNS system	not less than 2	2.4	separation on concrete
With the Mapecoat TNS system	not less than 0.5	0.27	separation on Base Coat
System solution #3			
Without the Mapecoat TNS system	not less than 2	1.9	separation on Nivoplan Plus
With the Mapecoat TNS system	not less than 0.5	0.37	separation on Base Coat
System solution #4			
Without the Mapecoat TNS system	not less than 2	2.2	separation on concrete
With the Mapecoat TNS system	not less than 0.5	0.3	separation on Base Coat



a b

Fig. 12. Cohesive destruction: a – material in Mapecoat TNS Base Coat layers; b – concrete material of the bridge

Characteristic types of breaks in the material of structures are shown in figure 13.

Later, the compressive strength of the samples was determined. At the same time, in addition to the planned research of samples to determine the compressive strength, studies were performed to determine the ultimate tensile strength during bending. The tests were carried out on samples guided by the methods of DSTU B V.2.7-126:2011 "Dry modified construction mixes, General technical conditions", DSTU B V.2.7-239:2010 "Construction solutions and Test methods" (EN 1015-11:1999, NEQ).

The lintel samples were a fragment of the finished coating cut from a reinforced concrete beam. Samples measuring 40 (height) x 40 (width) x 160 (length) mm were cut out for testing.

The calculation was carried out following DSTU B V.2.7-248:2011 Wall materials. Methods of determining strength limits in compression and bending (GOST 8462-85, MOD). The results of the research are given in Table 4.

The tests were carried out on cube samples formed after breaking the beams, following DSTU B V.2.7-126:2011 "Dry modified building mixes. General technical conditions", DSTU B V.2.7-239:2010 "Construction solutions. Test methods" (EN 1015-11:1999, NEQ). The limit of compressive strength was calculated as the average value from tests of three samples according to DSTU B V.2.7-214:2009 "Building materials. Concretes. Methods of determination of strength according to control samples".

The results of the research are given in Table 4.

Table 2. Results of studies of the adhesion strength of the layers of structures to each other and to the base after their alternate freezing.

The construction under study	Adhesion strength to the base, MPa		Notes
	normative (recommended by the manufacturer)	defined	
System solution #1			
Without the Mapecoat TNS system	not less than 2	-	when cut, CD24 (5mm) peeled off
With the Mapecoat TNS system	not less than 0.5	0.26	separation on Base Coat
System solution #2			
Without the Mapecoat TNS system	not less than 2	2.1	separation on concrete
With the Mapecoat TNS system	not less than 0.5	0.25	separation on Base Coat
System solution #3			
Without the Mapecoat TNS system	not less than 2	0.06	took off from Nivoplan Plus
With the Mapecoat TNS system	not less than 0.5	0.31	2 pcs. – break on Base Coat 1 pc. – broke away from the I 600
System solution #4			
Without the Mapecoat TNS system	not less than 2	2.1	separation on concrete
With the Mapecoat TNS system	not less than 0.5	0.3	separation on Base Coat

Table 3. The results of studies of the adhesion strength of the layers of structures that were under the Mapecoat TNS system, between each other and with the base after their alternate freezing

Adhesion strength to the base, MPa		Notes
normative (recommended by the manufacturer)	defined	
System solution #1		
not less than 2	2.0	separation on concrete
System solution #2		
not less than 2	2.2	took off from Nivoplan Plus
System solution #3		
not less than 2	1.7	separation on concrete
System solution #4		
not less than 2	2.2	separation on concrete

Thus, the proposed methodology, which is based on the phased implementation of experimental studies of the proposed design and technological solutions for the restoration of the bicycle track, made it possible to investigate their effectiveness in the laboratory under various possible operating conditions and to select the best ones and provide recommendations for their improvement. And the results obtained can be used in restoration work or new construction at similar or similar facilities.

Based on the results of a number of experimental studies, recommendations were provided regarding the expediency/impropriety of using the studied system solutions. Recommendations are also provided for the replacement of individual materials in the coatings provided for by the project to improve the physical and mechanical performance of the system solution as a whole.

Recommendations are also given on the technology of work during the preparation of the base and application of layers.

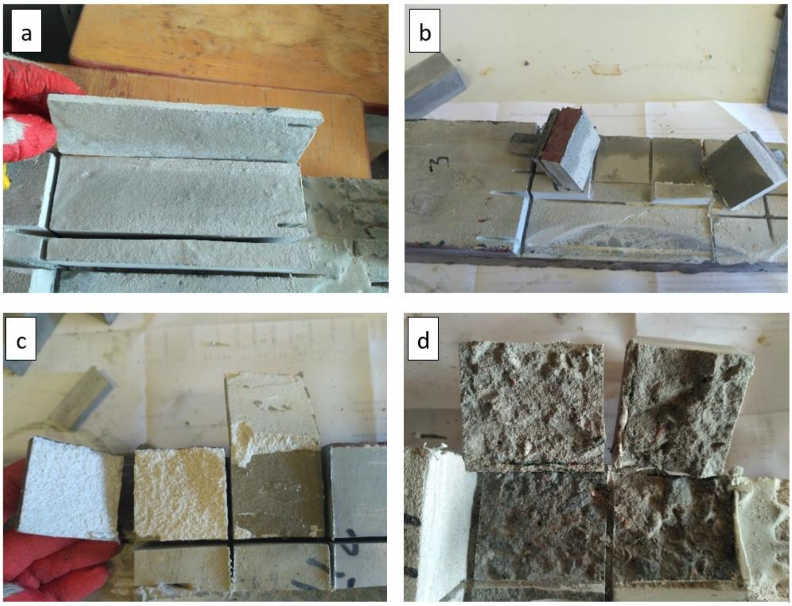


Fig. 13. Characteristic types of breaks in the materials of system solutions: a – detachment of Ceresit CD24 (5mm) when cutting sample No. 1; b – detachment of the Ceresit CD24 adhesive layer from Nivoplan Plus on sample No. 3; c – cohesive and adhesive rupture of the Mapecoat TNS system on sample No. 3a; d – cohesive destruction of the bridge concrete material when determining the adhesion on sample #2

Table 4. Results of bending and compressive strength studies of samples selected from the intended coatings.

The construction under study	**Adhesion strength to the base, MPa**		**Notes**
	normative (recommended by the manufacturer)	**defined**	
System solution #1			
Without the Mapecoat TNS system	>5-7,5/7,24	>20-30/22,4	
With the Mapecoat TNS system	>5-7,5/7,24	>20-30/21,7	the TNS coverage has been compressed
System solution #2			
Without the Mapecoat TNS system	>5-7,5/7,54	>30-35/32,1	
With the Mapecoat TNS system	>5-7,5/7,57	>30-35/31,5	the TNS coverage has been compressed
System solution #3			
Without the Mapecoat TNS system	>5-7,5/6,8	>20-30/26,4	
With the Mapecoat TNS system	>5-7,5/6,7	>20-30/22,3	the TNS coverage has been compressed
System solution #4			
Without the Mapecoat TNS system	>5-7,5/6,0	>30-35/32,1	
With the Mapecoat TNS system	>5-7,5/6,2	>30-35/33,4	the TNS coverage has been compressed

Kyiv Velodrome at the final stage of restoration works is presented in figure 14.

Fig. 14. The Kyiv is in the final stage of work.

After the reconstruction, the Kyiv Velodrome is 286 meters of concrete-surfaced bicycle track with a width of 8m in bends. The angle of maximum inclination is 38°; transverse angle in a straight line – 11°; the length of the transition curve is 21.5m; permanent turning radius – 21.7m; permissible speed – 73.58km/h. In the centre there is a ramp for performing tricks and around the perimeter there are several tracks with different surfaces [2].

Conclusions

Kyiv Velodrome is the oldest sports facility in Ukraine and one of the oldest in Europe. In October 2014, in accordance with the order of the Ministry of Culture of Ukraine No. 869, the Kyiv cycle track was again granted the status of an architectural monument. In 2016-2017, a major restoration of the bicycle track surface, the administrative building, the construction of an underground parking lot and the reorganization of the adjacent territory were carried out.

As part of the scientific and technical support, an examination of the velodrome track was carried out with the determination of all existing defects and damages and as a result, recommendations for their elimination were provided. In particular, solutions have been developed to repair cracks and recommended measures are aimed at preventing their appearance in the future. Also, within the scope of research work, a number of experimental studies were carried out with the designed constructions of the cycle track for their compliance with the technical documentation and for the purpose of establishing durability.

The analysis of research results established that all system solutions provide the necessary compressive and bending strength. However, significant deviations of the established indicators of the adhesion strength of the layers of structures between themselves and with the base from those recommended by the manufacturers of building materials were found. According to the results of the research, the following solutions can be recommended for use in the object of restoration of the bicycle track:

1. System solution No. 2 and 4 without the Mapecoat TNS system.

2. System solution No. 1 and 3 without the Mapecoat TNS system require additional research to establish the reasons for the adhesive separation below the normative indicators from the Nivoplan Plus + Planecrete layer and the delamination of Ceresit CD24 when cutting the samples.

3. The Mapecoat TNS finish coating system solution needs further research to establish the reasons for the adhesive and cohesive separation of the material below the indicator set by the manufacturer.

However, it is known that currently TM "Mapei" has improved the Mapecoat TNS system. Currently, it is less picky about the influence of external factors in the process of its arrangement and stably provides the necessary parameters.

The methodology proposed in this publication is based on the phased implementation of experimental studies of the proposed design and technological solutions for the restoration of the bicycle track. The use of this approach made it possible to investigate the effectiveness of various design and technological solutions under various possible operating conditions in the laboratory and select the best ones, as well as provide recommendations for their improvement. Thus, the results obtained can be used in restoration work or new construction at similar or similar facilities.

References

[1] Yu. Salii, *History and future of Kyiv Velodrome*, **Khmarochos,** 2015. https://hmarochos.kiev.ua/2015/10/28/istoriya-ta-maybutnye-kiyivskogo-velotreku/ (Original language: Ю. Салій, *Історія та майбутнє Київського велотреку*, **Хмарочос,** 2015, https://hmarochos.kiev.ua/2015/10/28/istoriya-ta-maybutnye-kiyivskogo-velotreku/).

[2] T. Asadcheva, *The capital's velodrome is 110 years old: what is known about the city's oldest sports facility*, **Vechirnii Kyiv,** 2023, https://vechirniy.kyiv.ua/news/87227/ (Original language: Т. Асадчева, *Столичному велотреку — 110 років: що відомо про найдавнішу спортивну споруду міста*, **Вечірній Київ**, 2023, https://vechirniy.kyiv.ua/news/87227/).

[3] *Kyiv Cycle Track successfully reported on its activities and presented its development strategy*, **Official portal of Kyiv**, 08.11.2018, https://kyivcity.gov.ua/news/kivskiy_velotrek_uspishno_vidzvituvav_pro_svoyu_diyalnist_ta_prezentuvav_strategiyu_rozvitku/ (Original language: *Київський велотрек успішно відзвітував про свою діяльність та презентував стратегію розвитку*, **Офіційний портал Києва,** 08.11.2018, https://kyivcity.gov.ua/news/kivskiy_velotrek_uspishno_vidzvituvav_pro_svoyu_diyalnist_ta_prezentuvav_strategiyu_rozvitku/)

[4] *Battle for the bike track,* **Newsletter "Klitschko is Mayor"**, 12.2017 https://kyiv.klichko.org/wp-content/uploads/newspaper/udar_32.pdf (Original language: *Битва за велотрек*, **Інформаційний бюлетень "Кличко - мер",** 12.2017 https://kyiv.klichko.org/wp-content/uploads/newspaper/udar_32.pdf)

[5] *What will be the new Kiev Cycle Track, which opens this weekend.* **Big City Magazine,** 16.05.2017, https://bzh.life/gorod/gorod-velotrek-kartochka/ (Original language: *Каким будет новый Киевский велотрек, который открывают на выходных.* **Журнал большого города,** 16.05.2017, https://bzh.life/gorod/gorod-velotrek-kartochka)

[6] O. Zlyvkova, *Kyiv Velodrome. Hopes for the best,* **Cultural heritage of Kyiv: research and protection of the historical environment,** ArtEk, Kyiv, 2003, pp. 131-133. (Original language: О. Зливкова, *Київський велотрек. Надії на краще*, **Культурна спадщина Києва: дослідження та охорона історичного середовища,** АртЕк, Київ, 2003, сс. 131 – 133. с. 131 – 133.)

[7] *** *, Law of Ukraine "On the accession of Ukraine to the Second Protocol to the Hague Convention on the Protection of Cultural Property in Cases of Armed Conflict of 1954"** dated April 30, 2020 No. 585-IX. (Original language: **Закон України «Про приєднання України до Другого Протоколу до Гаазької конвенції про захист культурних цінностей у випадках озброєного конфлікту1954 року»** від 30 квітня 2020 року № 585-IX.)

[8] A. Pawłowska, A. Gralińska-Toborek, P. Gryglewski, O. Sleptsov, O. Molodid, O. Ivashko. M. Początko, *Problems of Expositions and Protection of Banksy's Murals in Ukraine*, **International Journal of Conservation Science, 14**(1), 2023, pp. 99-114. DOI: 10.36868/IJCS.2023.01.08.

[9] **Law of Ukraine "On Protection of Cultural Heritage"** dated 06/08/2000 No. 1805-III. (Original language: **Закон України «Про охорону культурної спадщини»** від 08.06.2000 № 1805-III.)

[10] O. Molodid, O. Kovalchuk, V. Skochko, R. Plokhuta, O. Molodid, I. Musiiaka, *Inspection of war-damaged buildings and structures by the example of urban settlement Borodianka*, **Опір матеріалів і теорія споруд / Strength of Materials and Theory of Structures, 110,** 2023, pp. 328-343. DOI: 0.32347/2410-2547.2023.110.328-343.

[11] *** ***,DSTU-N B V.3.2-4:2016. Instructions on the execution of repair and restoration works on monuments of architecture and urban planning,** Ministry of Regional Development, Construction and Housing and Communal Services of Ukraine, Kyiv, 2016. (Original language: **ДСТУ-Н Б В.3.2-4:2016. Настанова щодо виконання ремонтно-реставраційних робіт на пам`ятках архітектури та містобудування,** Мінрегіон України, Київ, 2016.)

[12] *** ***,DSTU B V.3.1-2:2016. Repair and strengthening of load-bearing and enclosing building structures and foundations of buildings and structures,** Ministry of Regional Development, Construction and Housing and Communal Services of Ukraine, Kyiv, 2016. (Original language: **ДСТУ Б В.3.1-2:2016. Ремонт і підсилення несучих і огороджувальних будівельних конструкцій та основ будівель і споруд,** Мінрегіон України, Київ, 2016.)

[13] O. Molodid, R. Plohuta, O. Molodid, I. Musiiaka, *Typical technological map for the restoration of stone structures (using materials and system solutions of TM MAPEI)***,** Kyiv, 2023. (Original language: О. Молодід, Р. Плохута, О. Молодід, І. Мусіяка, С. Бендерський. **Типова технологічна карта на відновлення кам'яних конструкцій,** Київ, 2023.)

[14] R. Plokhuta, H. Tonkacheiev, O. Molodid, O. Galinskyi, I. Rudnieva, I. Priadko, *The technology of crack repair by polymer composition*, **Опір матеріалів і теорія споруд / Strength of Materials and Theory of Structures, 108**, 2022, pp. 203-216. DOI: 10.32347/2410-2547.2022.108.203-216.

[15] O.M. Galinsky, O.S. Molodid, N.V. Sharikina, R.O. Plokhuta, *Research of technologies for restoration of the concrete protective layer of reinforced concrete constructions during the reconstruction of the buildings and structures,* **Innovative Technology in Architecture and Design (ITAD 2020), 21–22 May 2020, Kharkiv, Ukraine, IOP Conference Series: Materials Science and Engineering, 907,** Article Number: 012056. DOI: 10.1088/1757-899X/907/1/012056.

[16] H. Shpakova, A. Shpakov, W. Kripak, V. Koliakova. *Structural and Technological Aspects of Conservation of Street Art on Buildings Damaged During the War*, **International Journal of Conservation Science, 15**(1), 2024, pp. 103-108. DOI: 10.36868/IJCS.2024.SI.09.

[17] O.S. Molodid, *The system of forming structural and technological solutions for restoring the operational suitability of building structures***, Kyiv National University of Civil Engineering and Architecture**, Kyiv, 2021. (Original language: О.С. Молодід, *Система формування конструктивно-технологічних рішень відновлення експлуатаційної придатності будівельних конструкцій***,** Київський національний університет будівництва і архітектури, Київ, 2021.)

[18] A. Moloded, *Experimental studies of the technology of strengthening reinforced concrete columns with carbon fibers,* **Science and Technology. International Scientific and Technical Journal BNTU, 19**(5), 2020, pp. 395–399. (Original language: А. Молодед, *Экспериментальные исследования технологии усиления железобетонных колонн углеродными волокнами,* **Наука и Техника. Международный научно-технический**

журнал БНТУ, 19(5), 2020, сс. 395–399.). DOI: 10.21122/2227-1031-2020-19-5-395-399.

[19] M. Orlenko, M. Dyomin, Y. Ivashko, A. Dmytrenko, P. Chang. *Rational and aesthetic principles of form-making in traditional Chinese architecture as the basis of restoration activities,* **International Journal of Conservation Science, 11**(2), 2020, pp. 499-512.

[20] M. Orlenko, Y. Ivashko, I. Buzin, A. Dmytrenko, M. Krupa, *Modern Technologies in Restoration of Architectural Monuments (on the Example of St.Volodymyr`s Cathedral in Chersonesos),* **International Journal of Conservation Science, 13**(3), 2022, pp. 841-854.

[21] M. Orlenko, Y. Ivashko, J. Kobylarczyk, D. Kusnierz-Krupa, *Ways of revitalization with the restoration of historical industrial facilities in large cities. The experience of Ukraine and Poland.* **International Journal of Conservation Science, 11**(2), 2020, pp. 433-450.

[22] M. Dyomin, A. Dmytrenko, D. Chernyshev, O. Ivashko. *Big Cities Industrial Territories Revitalization Problems and Ways of Their Solution,* **Proceedings of the 2nd International Conference on Building Innovations, ICBI 2019, Lecture Notes in Civil Engineering, 73,** 2019**,** pp. 365-373.

[23] M. Orlenko, Y. Ivashko, D. KuśnierZ-Krupa, J. Kobylarczyk, O. Ivashko. *Conservation of the Residential and Public Architecture of the 19th- Early 20th Centuries (on the Examples of Kyiv and Cracow),* **International Journal of Conservation Science, 12**(2), 2021, pp. 507-528.

[24] R. Akselrod, A. Shpakov, G. Ryzhakova, T. Honcharenko, I. Chupryna, H. Shpakova. *Integration of Data Flows of the Construction Project Life Cycle to Create a Digital Enterprise Based on Building Information Modeling,* **International Journal of Emerging Technology and Advanced Engineering, 1,** 2022, pp. 40-50. DOI: 10.46338/ijetae0122_05.

[25] O. Molodid, R. Plokhuta, O. Molodid, M. Początko, K. Janicka-Świergula, V. Skochko, Y. Novak, *Research of the Component Composition of Drying Renovation Brick Crumb Plaster for Restoration of Architectural Monuments,* **International Journal of Conservation Science, 15**(1), 2024, pp. 89-102. DOI: 10.36868/IJCS.2024.si.08.

[26] O. Molodid, V. Skochko, R. Plokhuta, O. Molodid, I. Musiiaka, S. Benderskyi, S. Bogdan. *Modern Restoration Methods For Damaged Historical Buildings As A Result of Military Aggression. Case of Educational Institutions,* **International Journal of Conservation Science, 15**(1), 2024**,** pp. 205-220. DOI: 10.36868/IJCS.2024.si.17.

[27] O. Molodid, I. Umanets, O. Murasova, N. Chukanova et al., **Report on the research work "Scientific and technical support on the object "Restoration with adaptation for modern use of the bicycle track at 58 Bohdana Khmelnytskoho Street and improvement of the territory within Bohdana Khmelnytskoho, Mykhailo Kotsiubynskoho and Viacheslava Lypynskoho Streets in Shevchenkivskyi District of Kyiv",** Kyiv, 2017. (Original language: О. Молодід, І. Уманець, О. Мурасьова, Н.Чуканова та ін. **Звіт про НДР «Науково технічний супровід на об'єкті "Реставрація із пристосуванням для сучасного використання велотреку на вул. Богдана Хмельницького, 58 та благоустроєм території у межах вулиць Богдана Хмельницького, Михайла Коцюбинського та Вячеслава Липинського у Шевченківському районі міста Києва",** Київ, 2017.)

[28] * * *, https://www.mapei.com/ua/uk/materialy-i-tekhnichni-rishennia [accessed on 12.12.2023].

Received: March 10, 2024
Accepted: September 2, 2024