INTERNATIONAL JOURNAL OF CONSERVATION SCIENCE
ISSN: 2067-533X Volume 17, Issue 3, July-September 2026: 853-866 www.ijcs.ro
DOI: 10.36868/IJCS.2026.03.02

ASSESSMENT OF CRACK INJECTION METHODS IN THE RESTORATION OF HISTORIC BRICK BUILDINGS

Oleksandr MOLODID[1,*], Sergii BENDERSKYI[1], Ruslana PLOKHUTA[1], Sergey BOGDAN[2], Volodymyr SKOCHKO[1], Yevheniia NOVAK[3], Katarzyna SŁUCHOCKA[4]

[1] Kyiv National University of Construction and Architecture, 31 Povitryanykh Syl Avenue, Kyiv, 03037, Ukraine
[2] Prydniprovska State Academy of Civil Engineering and Architecture, Technology of Building Materials, Products and Structures Dept., 24-a Architect Oleh Petrov Street, Dnipro, 49005, Ukraine
[3] Yuriy Fedkovych Chernivtsi National University, 2 Kotsiubynskoho Street, Chernivtsi, 58012, Ukraine
[4] Faculty of Architecture, Poznan University of Technology, 60-965 Poznan, Poland

Abstract

The article is devoted to studying the modern repair materials used for eliminating cracks in brick walls by injection, the main repair method for cultural heritage sites, ensuring maximum preservation of their authenticity. Experimental studies were conducted to determine the possibility of using modern repair materials (high-flow cement mortar Stabilcem and polymer compositions Epojet and Edmok) to repair brickwork cracks. The best results were observed in polymer compositions. The possibility of restoring the cracked samples' bending strength after the repair mortar's injection was tested. After injecting a crack with an opening width of 2-3 mm (for polymer compositions) and 6-8 mm (for cement composition), the restored samples' bending strength was 125.6% of the previous for Stabilcem, 182.5% for Edmok, and 315% for Epojet. When the cracks were previously filled with coarse quartz sand with an opening width of 4-5 mm (for polymer compositions) and 10-12 mm (for cement compositions), the repaired samples' bending strength was 67% of the previous for Stabilcem, 174.9% for Edmok, and 161% for Epojet. The study's results indicate the possibility of using polymer compositions for crack repair with masonry structural restoration in both empty and sand-filled cracks and Stabilcem for masonry structural restoration in empty cracks.

***Keywords**: Historical building; Damage; Restoration of structures; Masonry; Crack; Injection; Injectable solution; Reinforcement; Restoration*

Introduction

Cultural heritage sites of Ukraine, represented by buildings or structures that have preserved their authentic appearance and contain information and evidence about events and the lives of prominent people, are an integral part of Ukrainian culture and history. An extremely important aspect is the preservation of historical buildings for future generations.

Brick is the most common material used for the construction of historical buildings. Its use allowed the construction of objects with complex and visually attractive architectural forms while providing the necessary strength, reliability, safety, and comfort. It should be noted that the strength was provided by a significant thickness of the walls, which in turn provided the buildings with relatively sufficient energy efficiency. However, over time, all buildings lose their operational suitability and, as a result, acquire deformations and damage, and the structures lose

* Corresponding author: molodid2005@ukr.net

their load-bearing properties. The building generally becomes unusable for further operation or in an emergency condition and requires repair and restoration work.

Currently, Ukraine is experiencing the Russian Federation's military aggression, which has a significant impact on the technical condition of both separate building structures and buildings and structures as a whole, regardless of their distance from the front line, which is associated with massive shelling with missiles and UAVs. Almost every day, various means of destruction hit the objects in the territory of Ukraine, causing new damage [1], [2], [3].

The author's team inspects buildings and structures that have suffered various damages, including architectural monuments and historical buildings, to assess their technical condition. It should be noted that at first glance, when examining the buildings from a certain distance, they may have a neat and well-groomed appearance, as a result of which it seems that they are in normal technical condition. However, upon closer inspection, during their technical inspections, many defects and damages are revealed. Some of them may indicate either a poor or even critical condition of a separate structure or the building as a whole. As an example, we can consider the inspected historical buildings from different regions of Ukraine (Fig. 1).

Fig. 1. Examples of historical buildings with cracked brick walls: a – Andrushivka Lyceum No. 1 with a primary school (Zhytomyr region); b) Balta Oles Gonchar Lyceum No. 1 (Odesa region); c) Izmail Lyceum No. 1 (Odesa region); d) Izmail Gymnasium No. 2 (Odesa region).

According to the results of the survey of a large number of both historical and modern buildings, it was found that the most common damage to brick walls is cracks (Fig. 2). Cracks in structures primarily affect the overall aesthetic appearance of buildings and the comfort of people staying in them. However, from a technical point of view, cracks in structures can lead to a decrease in their load-bearing capacity and the possibility of further damage or even destruction of the structure itself or the whole building.

To clarify the real condition of the structural elements and the building as a whole, a visual and instrumental inspection is performed, the result of which is a technical inspection report indicating all detected damage, providing conclusions and recommendations for the necessary repair and restoration work to ensure further reliable operation of the facility.

Fig. 2. Examples of historical buildings' cracked walls: a – Andrushivka Lyceum No. 1 with a primary school (Zhytomyr region); b) Balta Oles Gonchar Lyceum No. 1 (Odesa region); c) Izmail Lyceum No. 1 (Odesa region); d) Izmail Gymnasium No. 2 (Odesa region).

As an example, excerpts from technical inspection reports with separate descriptions of defects and damage to facades for the above-mentioned buildings are provided, recording all existing damage (Fig. 3).

Fig. 3. Excerpts from inspection reports of damaged buildings, where red lines show cracks and red hatching shows masonry destruction: a – Andrushivka Lyceum No. 1 with a primary school (Zhytomyr region); b) Balta Oles Gonchar Lyceum No. 1 (Odesa region); c) Izmail Lyceum No. 1 (Odesa region); d) Izmail Gymnasium No. 2 (Odesa region)

The Law of Ukraine "On the Protection of Cultural Heritage" [4] provides for the following types of work on damaged cultural heritage sites: conservation, restoration, rehabilitation, museumization, repair, and adaptation of monuments.

An analysis of the normative literature [5] has established that when performing repair and restoration work on cultural heritage sites, it is recommended to focus on the following principles:

– minimal intervention in the structure of the building or structure, maximum preservation of authenticity;

– the repair material must be reversible, that is, one that can be easily removed if necessary, for repeated repair/restoration, etc.

Typically, for the repair of cracks in the masonry of historical buildings or architectural monuments, it is recommended [5-7] to use the technology of injecting mortar into them under low pressure. In this case, the material must have the following characteristics: high permeability; not delaminate; not create efflorescence; sufficient adhesion to the body of the structure; compliance of physical and mechanical indicators after hardening with the indicators of the masonry mortar, optimal water release and water retention, and viability of at least 1 hour. As a mortar, it is proposed to use either lime-based solutions or Portland cement-based solutions. It is also permissible to use fillers in the form of marble, quartz, limestone, or other flour. Following the requirements of the standards [5], the repair material must be as close as possible to the existing masonry mortar material.

However, during restoration, if necessary, it is possible to use modern approaches, materials, and technologies [8-11]. For injection of cracks, the following injection solutions are permissible: lime-cement and cement solutions, highly fluid solutions, special salt-resistant mixtures based on lime and eco-pozzolans, and solutions based on polymer resins, mainly two-component ones.

Every year, the number of buildings that can be attributed to cultural heritage sites is increasing worldwide, so interest in research and development of crack repair technologies and the search for new materials is constantly growing. Depending on the region and the characteristics of the building material that was used in the construction of historical buildings, various technologies for the repair and restoration of structural elements and buildings as a whole are distinguished [12-14].

In general, there are many repair and reinforcement technologies for repairing masonry cracks using various repair materials [3], [7], [15-20]. However, the use of most methods of repairing and reinforcing masonry with cracks is not possible in cultural heritage sites. Injection technology is one of the few technologies that, depending on the repair material, allow not only filling cracks of different widths and natures but also, in some cases, restoring structural integrity without changing the appearance with minimal intervention in the structure.

The use of lime-based mortars or other materials used for masonry in ancient times as a repair material allows you to create a material as close as possible to the authentic one [17]. In this case, the crack is filled without changing the appearance of the damaged structural element. However, this repair method is advisable to use if the crack is stabilized, i.e., such that it will not expand over time and the structure will not be exposed to compressive loads. Otherwise, the effect of filling the crack will be short-lived, the repair material will crack and exfoliate [18], and there will be a need for repeated repair. It should be understood that materials such as lime, cement, and other authentic materials have a plastic consistency and are not suitable for injection. Adding a large amount of water to ensure fluidity of the mixtures will lead to their significant plastic shrinkage in the cracks with subsequent delamination. Injection of small cracks with an opening width of up to 2 mm with such solutions is practically impossible.

Given that most damaged cultural heritage sites have cracks of a sedimentary or forceful nature, it is advisable to consider the possibility of using other, more durable and reliable solutions for their repair, which are guaranteed to restore the structural integrity of the structures. Such solutions include polymer-cement, microcement, and polymer. However, it is worth remembering that it is necessary to carry out work on injecting or filling cracks with repair solutions only after the stabilization of crack formation, i.e., elimination of the causes of their occurrence, such as building subsidence of footings and foundations or concentrated loads.

The goal of the work is research into the technology of cracks' injection in brick structures, including for historical buildings.

Materials and Methods

In line with the study's purpose, the following general scientific methods were used:

– visual – determination of the technical condition of the historical buildings' structures by external signs;

– analytical – assessment of the technical condition of the surveyed objects;

– experimental—conducting research in laboratory conditions to determine the strength indicators: adhesive strength when bonding the repair material and the body of the structure; bending strength of structures restored with injection materials;

– comparative analysis method for assessing the research results obtained in laboratory conditions.

For the study, the following sources were used:

1) legislative framework [4], [5];

2) issues related to repairing cracked technologies for historical buildings' masonry [5-7], [17], [18];

3) issues related to technologies for repairing cracks in masonry [3], [7], [15], [16];

4) issues related to the need to use modern materials and technologies for repairing cracks in masonry of historical buildings [8-14];

5) issues related to establishing the technical condition of buildings and structures damaged by military actions [1], [2].

The study of the issue of repairing cracks in the masonry of historical buildings and structures has demonstrated the need to search for and research new repair technologies or improve existing technologies using modern repair injection materials in order to preserve cultural heritage sites.

Results and Discussion

A crack is damage to a structure, which is characterized by its fracture (partial or complete). On the structure surface, the crack manifests itself as a small curvilinear cavity, while the internal space of this damage is closed for visual inspection. Therefore, during the repair of cracks by their injection, monitoring the spread of the solution and the filling of the cracks is impossible, which does not allow us to state that the work is performed qualitatively.

The presence on the market of many different types of injection materials for brick structures raises questions about their effectiveness, area, technology of application, etc. It is also not clear what happens to different solutions during the injection and strength-gaining process. At the same time, the consumption of injection material in small cracks will be moderate, and in the presence of cracks with an opening width of more than 7 mm, the consumption of expensive materials that will really restore the structural integrity of structures may be inefficient from an economic point of view. It is the presence of the aforementioned questions that gave impetus to several scientific studies. After all, when providing recommendations or developing design solutions, you need to be sure that the intended solution for repairing cracks will give the necessary result, especially if these works are carried out on historical buildings.

To establish the possibility of using modern cement-based and polymer-based repair injection materials, a series of experimental studies was planned and conducted, which consisted of determining the flowability of selected materials along a conditional crack, determining the possibility of using coarse sand as a filler for wide cracks, and subsequently injecting repair solutions into them. To control the quality of the crack injection work performed, it was planned to determine the adhesive bond of the repair material to the structure body and determine the bending strength of the injected repaired samples.

First of all, experimental studies were conducted to determine the most effective repair materials, which will be used for further research. Thus, the following materials were selected as repair injection materials:

– Edmok for injection – two-component polymer high-flow composition (LLC Composite, Ukraine);

– Epojet – two-component super-fluid epoxy resin (LLC MAPEI Ukraine);

– Stabilcem – high-flow powder binder on a cement basis (LLC MAPEI Ukraine).

Washed and dried quartz sand was used as filler for some studies.

The studies were divided into two stages.

At the first stage, the spread of the material along a conditional crack was investigated. For this, wall fragments were built from solid bricks, which were as close as possible to the bricks used in historical buildings. The dimensions of the wall fragments were 600×510×120 mm (Fig. 4). Since the main task was to determine the spread of the repair mortar along a conditional crack and at the same time establish its principle, it was planned to manufacture special experimental stands that would make it possible to visually control the process of filling cracks. For this, transparent organic glass was attached to the prepared wall fragment using a system of anchors, clamps, and puffs at a certain distance from the sample. Thus, for the injection of a polymer repair mortar, a conditional crack with an opening width of 2 mm was simulated, and for the injection of cement mortar, the width of the conditional crack was 4 mm.

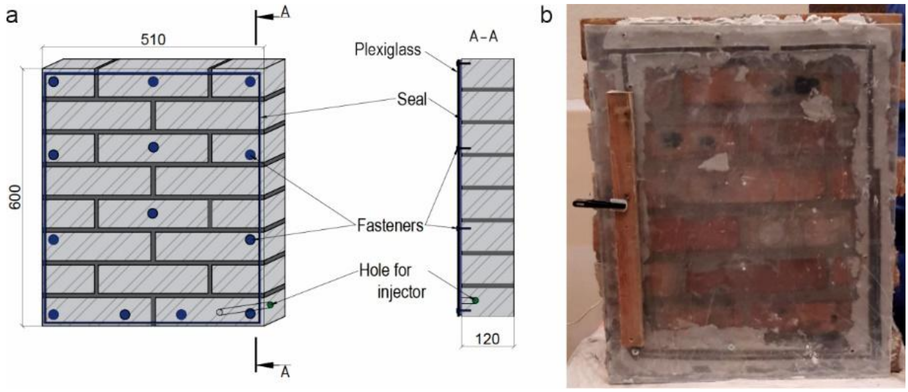

Fig. 4. General view of the sample for the experiment: a – schematic image; b – full-scale

A hole was drilled in the lower part of the samples, into which an injection packer was subsequently glued: plastic (Fig. 5a) – for injecting cement mortar; metal (Fig. 5b) – for injecting polymer compositions.

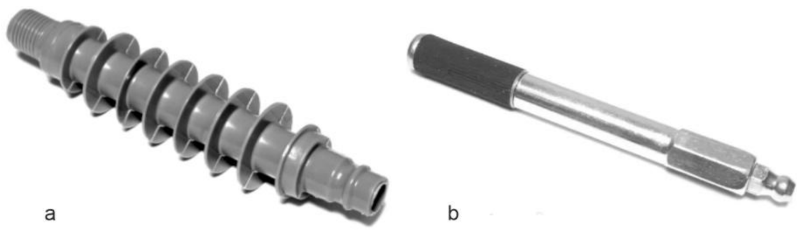

Fig. 5. Injection packers used for experimental studies: a – plastic; b – metal

To avoid leakage of the repair solution from the conditional crack simulated between the plexiglass and the sample, the crack was packed with the repair mortar along the perimeter. In this case, it could be either a gypsum mortar, which can be easily dismantled from the structure in the future, or any cement mortar. Injection of the solutions was carried out using special injection equipment, which allowed for uniform injection under low pressure (about 0.6 – 0.7 atm) using classical technology. During the injection process, 1.5 liters of polymer solutions and 2.5 liters of cement mortar were used. During injection with the polymer composition, no preliminary preparation of the base was performed (except for dust removal); before injecting the cement mortar, the sample was saturated with water. The injection process is shown in figure 6.

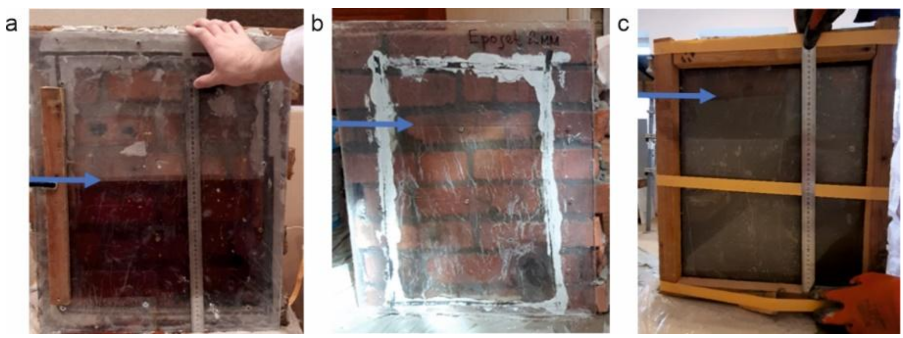

Fig. 6. The process of repair solutions' injection: a – Edmok for injection; b – Epojet; c – Stabilcem

When observing the injection process, it was noticed that the solutions were evenly distributed over the entire plane (width) of the conditional crack (slit) and freely filled in height. In general, the entire volume of repair materials was injected. The maximum height of the rise of repair solutions in conditional cracks was somewhat different, but this is due to the volume of repair material and the quality of the crack packing. During the injection, it was noticed that due to the high fluidity of the polymer compositions, they flowed even through the smallest cracks and microcracks in the structure. Therefore, when performing further experimental studies, this fact was taken into account, and all possible cracks were carefully packed before injection.

After the cement mortar had hardened and the other mortars had polymerized, the plexiglass was removed from the samples, and a detailed inspection was performed. As a result, it was found that the structural body was impregnated with polymer compositions, due to which the height of the polymerized mortar in the conditional crack decreased by approximately one-third. However, there was also a slight leakage of mortars through microcracks, which also affected the amount of repair material in the crack. As for the cement mortar, it can be stated that it penetrated the cracks and irregularities on the structure's surface, and a slight shrinkage occurred during its drying. A network of microcracks was observed on the surface of the repair mortar.

To establish the adhesive bond of the repair material to the base of the structures, the following study was conducted. Metal plates with dimensions of 50 x 50 mm were glued to the surface of the epoxy adhesive solutions. After polymerization of the glue, the plates were peeled off using a device for determining the tear-off force, which characterizes the value of the adhesive bond (Fig. 7) with preliminary cutting along the perimeter of the plates using an angle grinder.

Thus, the bond strength of the Edmok injection polymer composition with the base was, on average, 0.58 MPa; the Epojet polymer composition, 1.98 MPa; and the Stabilcem repair mortar, 0.23 MPa. At the same time, the type of adhesive connection for the Edmok injection and Epojet compositions was cohesive, i.e., the detachment of the plate occurred in the body of the brick, and for the Stabilcem mortar–adhesive, i.e., the detachment occurred at the junction of the repair mortar and the body of the structure (Fig. 8). However, it is worth noting that in all cases, regardless of the type of mortar, all cavities in the sample were filled with mortar. Since, when determining the bond strength of the Edmok and Epojet compositions, cohesive rupture occurred along the brick, it can be assumed that the established difference in the tear force indicators is associated with the different tensile strength of the brick itself, and the adhesion of polymers to the brick is similar and sufficient for structural restoration of walls with cracks.

The second stage of the research involved identifying the effectiveness of crack bonding with selected repair materials. Polymer compositions have proven themselves as an effective repair solution capable of bonding cracks with an opening width of up to 2–3 mm and cement mortar for cracks with an opening width of 3–6 mm. Therefore, in the above studies, cracks of exactly this opening width were simulated.

For experimental studies, samples (columns) were made of solid brick with dimensions of 250×120×365 mm (Fig. 9a). It was planned to create a crack on each one, which would later be repaired by injecting it. For this purpose, the test sample was installed in a press, on two supports at the edges, and a breakdown force was applied to it in the middle of the sample (Fig. 9b and c) with the value of the breakdown force on the bend fixed. At the same time, plywood was placed on top and bottom of the sample to level the sample, evenly transfer the load, and prevent cuts in the structure. This is the scheme of applying force to the samples to obtain a crack in the middle zone.

Next, the broken sample was cleaned of non-cohesive material, and the halves were connected with the formation of a crack using a probe of the required thickness. Thus, for the injection of polymer solutions, the following samples with cracks were prepared: 2–3 mm wide; for the cement mortar, samples with cracks 6–8 mm wide were prepared.

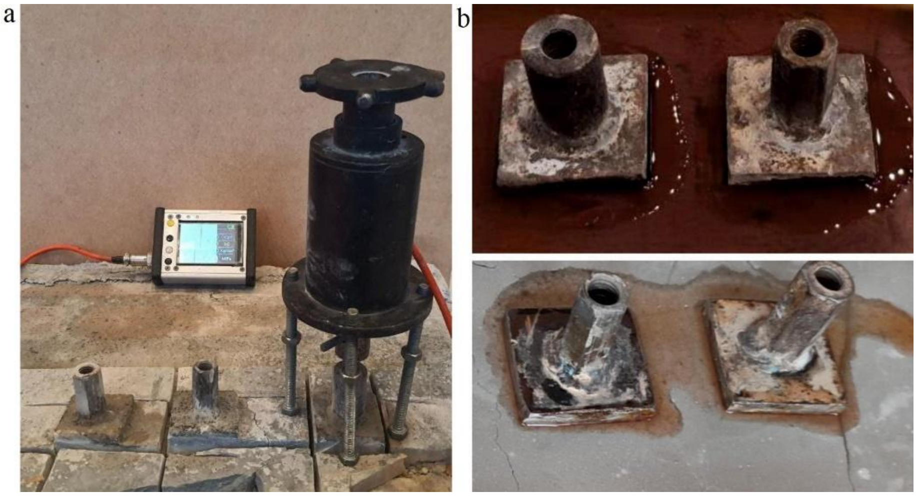

Fig. 7. The process of determining the magnitude and type of adhesive bond (a) and plates glued to the samples (b)

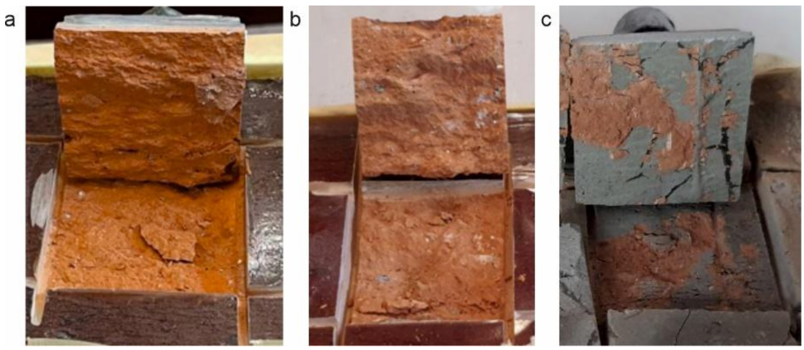

Fig. 8. Adhesive/cohesive connection of the repair mortar and the body of the structure (samples):
a – Edmok for injection; b – Epojet; c – Stabilcem

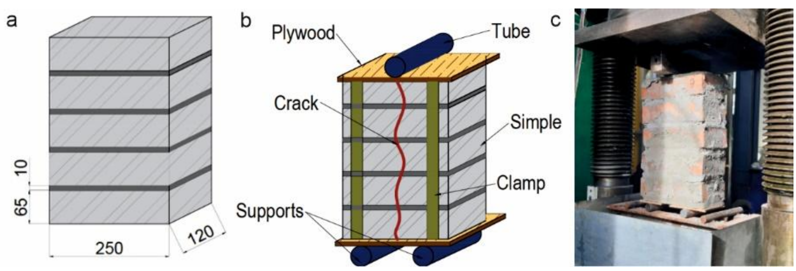

Fig. 9. General appearance of the experimental sample for experimental research:
a – schematic image of the sample; b – scheme of crack formation on the sample; c – test sample

It is worth noting that the width of the crack opening, as given above, was variable, which is associated with the configuration of the cracks that formed after breaking and removing the non-bonded parts. To prevent the leakage of the repair solution from the crack, the specimens were stamped with the repair solution along the entire perimeter. A small hole was left in the upper part of the specimens through which air escaped during the injection process.

After the repair packing mortar had hardened, holes were drilled in the lower section of the samples, into which, after cleaning, injection packers were glued (Fig. 5). In this case, in samples with a crack opening width of up to 4–5 mm, the holes were drilled at an angle of about 45° to the plane of the structure to a depth that allowed crossing the crack, and in samples with a crack opening width of 6 mm or more, the packer can be placed both at an angle to the plane of the structure and the crack and directly into the crack.

Injection was performed using classical technology with injection equipment. It is worth noting that the pressure of injection solutions into samples with empty cracks did not differ from that given above and was 0.6–0.7 atm. After the injection solutions had solidified, the cracks were repaired, and the samples were considered restored.

Subsequently, the samples were installed in a press, and forces were repeatedly applied to them, fixing breakdown values according to the scheme shown in figure 9. The values of breakdown forces before and after the experimental study are given in Table 1.

Table 1. Study of the efficiency of gluing cracks with repair solutions.

Injection solution	Breakdown force before injection, kN	Breakdown force after injection, kN	Recovery degree, %	Note
Stabilcem	39	49	125.6	The crack was formed along an old crack
Epojet	39	123	315	The crack formed next to the glued crack
Edmok for injection	40	73	182.5	

After testing the repaired samples, they were inspected, and the obtained values of the breakdown forces were analyzed. The general typical appearance of the samples after repeated application of the breakdown force is shown in figure 10.

It was found that under the condition of crack repairing with Stabilcem cement mortar, there was an increase in the breakdown force of the sample for empty cracks, which was 125.6% of the initial one. The crack formed in the same place as it was with the repair mortar. The inspection showed that the mortar completely penetrated all the cracks.

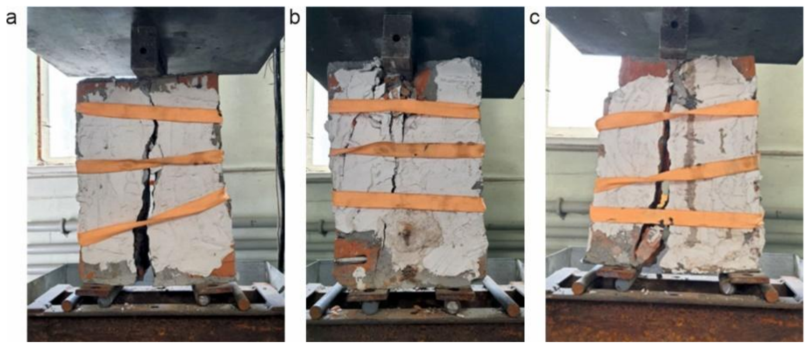

Fig. 10. General view of repaired experimental samples after repeated application of breakdown force: a – Stabilcem; b – Epojet; c – Edmok for injection

The values obtained after conducting an experimental study indicate the possibility of using Stabilcem mortar for repairing cracks in stone structures if it is necessary to restore the structural integrity of the masonry.

When the crack was repaired with the Epojet polymer composition, the value of the reapplied breakdown force was 315% of the initial value. In this case, a new crack formed next to the repaired one. A detailed inspection showed that the solution penetrated deep into the body of the structure. Therefore, the Epojet polymer composition can be recommended for repairing small cracks up to 3 mm.

When using the Edmok for injection polymer composition, the reapplied breakdown force was 182.5% of the initial value. The crack that formed after the reapplied breakdown force formed next to the glued one. Therefore, the Edmok injection polymer composition can be recommended for repairing cracks in masonry with an opening width of up to 3 mm.

It should be understood that the obtained increase in the bending strength of the experimental samples after repairing the cracks in them arose because they have a small length; that is, when applying a bending force, the force arm has a negligible value. The obtained results of experimental studies are interpreted as follows. If the bending strength of the restored samples is equal to or greater than that of the new sample, and a new crack appears next to the glued one, then the injection solution reliably glues the existing crack, and it will not appear in the same place; that is, the structural integrity of the structure is restored. If the bending strength of the restored samples is less than that of the new sample, and a new crack appears along the old one, then we believe that the injection solution did not reliably glue the crack but only filled it.

Since the results of experimental studies have high indicators and indicate the possibility of using the considered injection solutions for repairing cracks in masonry, it was decided to perform a similar study, but for cracks with a larger opening width. However, given the high cost of repair materials, it was decided to investigate the possibility of using coarse sand as a crack filler to reduce the technology cost.

Thus, for the injection of polymer solutions, samples with cracks with an opening width of 4–5 mm were prepared; for the cement solution, samples with cracks with a width of 10–12 mm were prepared. The preparation of samples for the experiment is described above. The only difference between the previous study and this one was the filling of the crack with sand before injection. Thus, quartz sand with a fraction of 1.1–1.8 mm was poured into the samples through a small hole in the upper part of the samples, through which air escaped during the injection process. In real conditions, sand can be blown into the cracks with a sandblasting device.

Injection was performed using classical technology and injection equipment. It is worth noting that the pressure of injection solutions into cracks with sand was reduced to ensure gradual and uniform impregnation of sand and filling of cracks with repair material. After the hardening of injection solutions, the samples were installed in a press, and repeated forces were applied to them with fixation of breakdown values according to the scheme shown in figure 9. The results of the study are given in Table 2.

Table 2. Study of the efficiency of gluing cracks with repair solutions with their previous filling with sand.

Injection solution	Breakdown force before the experiment, kN	Breakdown force after the experiment, kN	Recovery degree, %	Note
Stabilcem	41	27.5	67	The crack was formed along an old crack
Epojet	42.2	68	161	The crack formed next to the glued crack
Edmok for injection	39.8	69.6	174.9	

To compare the obtained values of the destructive forces under the condition of preliminary filling of cracks with coarse sand and the values of the destructive forces for empty cracks, the diagram shown in figure 11 was constructed.

After the experimental study, the results were evaluated, and the samples were inspected. It was found that when using Stabilcem mortar, the values of the re-applied destructive force were lower than during the initial application. The inspection showed that the repair mortar could not penetrate into the crack completely.

Fig. 11. Diagram of the bending strength of samples with cracks before and after their repair with injection materials

Therefore, it can be stated that the preliminary filling of the crack with sand and its subsequent injection with Stabilcem cement mortar does not allow the restoration of the original strength indicators of the masonry, but this method can be used simply for filling.

When injecting the crack with the polymer composition Epojet, the bending strength upon repeated application of the breakdown force increased and amounted to 161% of the previous value. The crack formed next to the glued one. The examination of the sample showed complete impregnation of the sand with the solution. The obtained research results allow us to state the possibility of using the injection solution for crack repair and structural restoration of stone structures.

A similar situation was observed when using the Edmok injection polymer composition. A new crack formed next to the repaired one. The value of the re-applied breakdown force was 174.9% of the previous value. Therefore, the Edmok injection repair polymer composition can be recommended for both the repair and structural restoration of cracked masonry.

Experimental studies have shown that when using polymer compositions, their leakage is possible even through the smallest cracks in structures; therefore, when using them, it is important to pack all possible cracks and gaps with a repair mortar.

Based on the results of experimental studies and the results of a visual and instrumental inspection of damaged objects, recommendations were developed regarding the need to inject cracks in masonry with polymer solutions or cement mortars on the above-mentioned objects.

Conclusions

A significant number of buildings and structures in Ukraine, including those of historical importance, have damaged masonry with cracks. This is facilitated by irreversible processes of materials aging, the influence of the environment, maintenance of buildings and structures, and military operations on Ukraine's territory that have taken place in recent years. Without timely repair and restoration work, structures may suffer further damage, and their destruction may accelerate.

The main condition for performing all repair and restoration work is to eliminate the causes of defects and damage. If it is necessary to repair cracks in stone structures, it is necessary to first carry out their inspection and assessment with the determination of the parameters of the cracks: width and depth of opening and spatial position; establish the dynamics of its development; take into account the condition of structural elements; and evaluate the material of the structures. Based on the results obtained, the most effective materials and technology for repairing cracks for a particular case are selected.

Crack injection is the most acceptable repair technology for historical buildings. According to regulatory documents, the repair of these damages of historical buildings must be carried out with mortars/solutions that are closest to the wall material. However, the analysis of scientific and technical literature indicates the need to find new, more effective modern materials that will allow not only filling the crack cavity but also restoring the structural integrity of the structure by reliably connecting (gluing) the separated parts of the structure.

In this regard, a number of experimental studies were performed to determine the possibility of using modern repair injection mortars for injecting cracks in stone structures, including historical buildings. Two polymer materials were used for the experimental study: Edmok for injection and Epojet and one cement mortar—Stabilcem.

The results of experimental studies show that with a crack opening width of up to 2 mm, it is possible to effectively use the studied polymer compositions Epojet or Edmok injection, which completely fill the crack and other voids in the structure while deeply penetrating the body of the structure and restoring its structural integrity. Thus, the bending strength of test samples after crack repair increases by 3.15 times when using the polymer composition Epojet and by 1.8 times when using the polymer composition Edmok for injection. With a crack opening width of up to 5 mm, it is economically feasible to use polymer injection compositions with preliminary filling of the crack with coarse sand. Thus, the strength of restored test samples with preliminary filling of the crack with sand increases by 1.14 times for the polymer composition Epojet and by 1.7 times for the polymer composition Edmok injection. However, when using polymer compositions, high-quality packing of the crack is a prerequisite to preventing material leakage.

Stabilcem repair cement mortar is advisable to use for repairing cracks in masonry when it is necessary to restore the masonry's structural integrity with an opening width of 3 mm or more. At the same time, the flexural strength of the repaired samples was 1.25 times greater than the strength of the unrepaired samples.

References

[1] O. Molodid, V. Scochko, R. Plokhuta, O. Molodid, I. Musiiaka, S. Benderskyi, and S. Bogdan, “Modern restoration methods for damaged historical buildings as a result of military aggression. Case of education institutions," *International Journal of Conservation Science,* vol. 15, spec. iss., 2024, pp. 205–220, DOI: 10.36868/IJCS.2024.SI.17

[2] O. Molodid, O. Kovalchuk, V. Skochko, R. Plokhuta, O. Molodid, and I. Musiiaka, “Inspection of war-damaged buildings and structures by the example of urban settlement Borodianka," *Strength of Materials and Theory of Structures,* no. 110, pp. 328–343, 2023; DOI: 10.32347/2410-2547.2023.110.328-343.

[3] O.S. Molodid, *Report on research work “Development of structural and technological solutions and practical recommendations for restoring the operational suitability of buildings and structures damaged as a result of hostilities."* Kyiv (in Ukrainian), 2024.

[4] Verkhovna Rada of Ukraine, Law of Ukraine “On the Protection of Cultural Heritage” No. 1805-III, *Bulletin of the Verkhovna Rada of Ukraine,* no. 39, p. 333, 2000.

[5] *DSTU-N B V.3.2-4:2016. Guidelines for performing repair and restoration work on monuments of architecture and urban planning,* Ministry of Regional Development, Construction, Housing, and Communal Services of Ukraine, Kyiv (in Ukrainian), 2011.

[6] I. Prokopenko, Ed. *Conservation and Restoration of Cultural Heritage Sites,* Kyiv: Samit-knyha (in Ukrainian), 2022.

[7] O. Molodid, R. Plohuta, O. Molodid, I. Musiiaka, and S. Benderskyi, *Standard method statement for the restoration of masonry structures,* Kyiv (in Ukrainian), 2023.

[8] M. Orlenko, Y. Ivashko, I. Buzin, A. Dmytrenko, and M. Krupa, “Modern technologies in restoration of architectural monuments (on the example of St. Volodymyr's Cathedral in

Chersonesos)," *International Journal of Conservation Science,* vol. 13, no. 3, pp. 841–854, 2022.

[9] M. Orlenko, Y. Ivashko, J. Kobylarczyk, and 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,* vol. 11, no. 2, pp. 433–450, 2020.

[10] M. Orlenko, Y. Ivashko, D. Kuśnierz-Krupa, I. Buzin, A. Dmytrenko, and J. Magiera, “Issues and Methods of Restoration of Kyivan Rus Period Foundation Masonry," *International Journal of Conservation Science,* vol. 15 spec. iss., pp. 335–348, 2024; DOI: 10.36868/IJCS.2024.si.25.

[11] O. Molodid, O. Molodid, I. Musiiaka, S. Benderskyi, O. Kozakova, A. Dmytrenko, and P. Bigaj, “Condition survey and recommendations regarding the repair of the facades of the historical building in the Besarabskyi quarter in Kyiv," *International Journal of Conservation Science,* vol. 14, no. 3, pp. 955–968, 2023; DOI: 10.36868/IJCS.2023.03.11.

[12] J. Yue, Y. Li, L. Zhao, J. Chen, Q. Deng, Z. Shi, and Z. Guo, “Experimental study on crack repair materials for masonry ancient building based on skeleton effect," *Journal of Building Engineering,* vol. 98, Article Number: 111442, 2024; DOI: 10.1016/j.jobe.2024.111442.

[13] Y. Hao, Z. Yao, R. Wu, and Y. Bao, “Damage and restoration technology of historic buildings of brick and wood structures: a review," *Heritage Science,* vol. 12, Article Number: 301, 2024; DOI: 10.1186/s40494-024-01422-y.

[14] R. Latifi, M. Hadzima-Nyarko, D. Radu, and R. Rouhi, “A Brief Overview on Crack Patterns, Repair and Strengthening of Historical Masonry Structures," *Materials,* vol. 16, no. 5, 1882, 2023; DOI: 10.3390/ma16051882.

[15] O. Molodid, R. Plokhuta, I. Musiiaka, and I. Reznichenko, “Sealing joints between concrete elements with polyurethane material," *Proceedings of Reliability and Durability of Railway Transport Engineering Structure and Buildings, Kharkiv, Ukraine, 17–19 November 2021, AIP Conference Proceedings,* vol. 2684, no. 1, Article Number: 040017, 2023; DOI: 10.1063/5.0120368.

[16] O.S. Molodid, “System of Formation of Constructive and Technological Solutions for the Restoration of the Operational Suitability of Building Structures." D.Sc. Dissertation, Kyiv National University of Construction and Architecture, Kyiv (in Ukrainian), 2021.

[17] O. Molodid, R. Plokhuta, O. Molodid, M. Poczatko, K. Janicka-Swiergula, V. Scochko, and Y. Novak, “Research of the component composition of drying renovation brick crumb plaster for restoration of architectural monuments," *International Journal of Conservation Science,* vol. 15, spec. iss., pp. 89–102, 2024; DOI: 10.36868/IJCS.2024.si.08.

[18] M. Abdel-Mooty, S. Khedr, and T. Mahfouz, “Evaluation of lime mortars for the repair of historic buildings," in: *Structural Studies, Repairs and Maintenance of Heritage Architecture XI WIT*, C.A. Brebbia, Ed. *Transactions on The Built Environment,* WIT Press, vol. 109, pp. 209–220, 2009; DOI: 10.2495/STR090191.

[19] Y. Ivashko, A. Dmytrenko, O. Molodid, O. Ivashko, V. Molochko, S. Belinskyi, and P. Bigaj, “The Destruction of the Established Urban Environment of Borodianka and Irpen as a Result of the Russian-Ukrainian War," *International Journal of Conservation Science,* vol. 15, no. 2, pp. 785–800, 2024; DOI: 10.36868/IJCS.2024.02.03.

[20] O. Molodid, V. Skochko, S. Bogdan, M. Pabich, K. Wysznacki, and J. Borowczyk, “Certain Aspects of Research Work in the Restoration of the Kyiv Velodrome," *International Journal of Conservation Science,* vol. 15, no. 3, pp. 1389–1406, 2024; DOI: 10.36868/IJCS.2024.03.15.

Received: January 20, 2026
Accepted: August 10, 2026