

# Restoration and strengthening of bearing brick columns using TM “MAPEI” materials

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**Abstract.** After the beginning of the full-scale Russian invasion of Ukraine, many buildings and structures received mechanical, thermal, or combined damages. Quick and high-quality restoration, strengthening, protection of reinforced concrete and brick load-bearing elements of structures of buildings and structures is an urgent problem today. That is why the application of modern technical solutions with the use of composite materials allows in the shortest possible time to restore and strengthening damaged structural elements without the use of material-intensive technologies and additional loading of buildings and foundations. In this article, the technology of restoration and strengthening of load-bearing brick columns using the Mapei FRG System is considered on the example of the restoration of a building in the city of Izyum. As a result, it was possible to restore and strengthen the bearing capacity of all elements of the building in the shortest possible time without the use of complex mechanisms and without additional load.

## 1 Introduction

The city of Izyum in the Kharkiv region was occupied almost at the beginning of the full-scale Russian invasion of Ukraine. Before the occupation, the city was regularly subjected to artillery and rocket-bomb attacks, which led to the destruction of almost 80% of the city's infrastructure [1].

In the surviving building of the city council, the occupiers set up a temporary “administration” where they worked and kept documentation until the liberation of the city.

The rapid advance of the Armed Forces of Ukraine led to the fact that the invaders did not have time to take out the documents and equipment and decided to dump everything in one pile on the first floor of the building and burn it. For this, a highly flammable explosive substance was used. As a result, after the fire was extinguished, the building had significant destruction (Fig. 1) on the first floor.

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**Fig. 1.** General view of the destruction on the first floor



**Fig. 2.** General view of the city administration building

The brick column structures lost their original load-bearing capacity and needed strengthening. The use of traditional strengthening methods using a metal bracket or a concrete shell would lead to the following negative consequences:

- A significant increase in the dimensions of the columns.
- Additional significant load on foundations.
- Long term of performance of works.
- Large material capacity and the need to use special equipment.
- The need for electricity for welding works, in case of its shortage.
- The reinforcement system should not create additional “cold bridges” in order for the building to be energy efficient.

An important requirement was to be completed before the onset of low temperatures (the start of work was to begin in September 2023).

## 2 Results

In the study, general scientific research methods were used, such as: **observation** – visual inspection of the structure, **research** – instrumental survey of the current state of the structure, **analysis** – processing of the received data to estimate the bearing capacity, **mathematical modeling** – creation of a mathematical model of strengthening the brick structure using the MAPEI FRG System strengthening system, **experiment** – checking the mathematical model in laboratory conditions to determine the strength indicators of the reinforced structure

For this study, the following data were used:

1. Regulatory base of Ukraine [2, 3].
2. Normative framework and EN requirements [5].
3. Technology of restoring and strengthening the bearing capacity of brick structures [4, 6-9].
4. Experience in the use of composite materials in Ukraine and abroad [8, 9].

The study of the above data became the basis for the analysis and selection of the technology for restoring and strengthening the load-bearing capacity of brick columns when applying modern system solutions using systems of composite materials **MAPEI FRG System**.

**When choosing a structural restoration system, it is necessary to consider that:**

- The linear expansion of the materials of the restoration and reinforcement system should be similar to the linear expansion of the structure itself.
- Additional “cold bridges” were not formed during the restoration, which could lead to deterioration of the building's energy efficiency.
- The reinforcement system should minimally additionally load the load-bearing structure in order not to perform additional reinforcement of the foundations and other structural elements.
- The technology of work should not be too complicated and require expensive equipment.
- The cost of the work must be economically justified and appropriate for use.

According to the completed report on the inspection of this building, it was necessary to strengthen the load-bearing capacity of brick columns, external walls and part of the window partitions using metal structures.

After performing the calculation of the metal capacity of the reinforcement system, it became clear that it is necessary to additionally strengthen the foundations in connection with the increase in the load from the reinforcement system. In addition, the use of metal structures creates “cold bridges”, which negatively affects the energy efficiency of the building. All these additional operations, additional foundations and other processes call into question the expediency of carrying out the restoration of this building. The cost of restoration and the cost of complete dismantling with subsequent new construction became comparable.

When the calculation of the system of restoration and strengthening of the brick structures of the building was carried out using modern composite materials based on two-component cement mortars in combination with a fiberglass mesh (MAPEI FRG System), it turned out that it is possible to strengthen the structures to their original bearing capacity without additionally increasing the load on the structures building, without deteriorating the energy efficiency of the building.

When calculating the cost, it was found that with a higher initial cost of materials (the cost of one meter of fiberglass mesh and repair solution is several times higher than the cost of one meter of a metal product), the final cost of the restored structure is almost 35% lower than the traditional reinforcement system, and the speed of work is minimal 4 times larger.

In this regard, it was decided to use the proposed reinforcement systems MAPEI FRG System and MAPEI FRP System to restore the load-bearing capacity of brick and reinforced concrete structures of the building.

Restoration of brick structures is carried out according to the following algorithm:

- surface preparation;
- base consolidation;
- repair of cracks, peeling areas and missing masonry elements;
- strengthening of structures using Mapei FRG System composite materials systems.
- Equipment of the restored structure.

According to the requirements of the European standard CNR DT 200/2004 [5], before starting the restoration process, brick structures must be cleaned of dirt, mold, salts and other

contaminants that impair the adhesion of repair solutions to the base. Brick columns were cleaned using a high-pressure hydrojet device.



**Fig. 3.** State of columns before and after cleaning

The second step is to consolidate the base by saturating it with a deep penetration primer that strengthens the base, reduces its absorption capacity, and improves the adhesion of subsequent repair layers.

The next stage is the masonry of the missing masonry elements and the repair of cracks (Fig. 4), which includes the following stages:

1. Filling the opening of the crack with solution from one or both sides of the structure to prevent the injection solution from leaking out of the crack.
2. Injection of a high-flow cement-based solution.



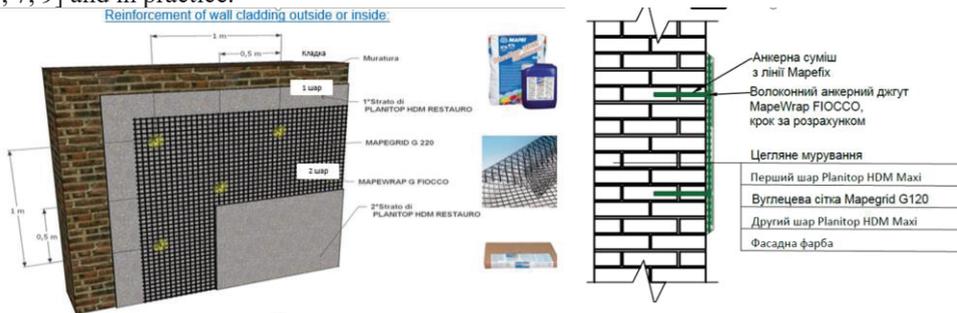
**Fig. 4.** Example of execution of injection works

Filling and repair of process holes after performing the above-mentioned types of work. After performing the work to restore the integrity of the brick column structure, before installing the reinforcement system, it is necessary to level the surface plane and also round the corners. The minimum rounding radius is 20 mm (Fig. 5).



**Fig. 5.** Leveling the plane of the columns

Reinforcement of the brick structure of the columns is carried out after the completion of all the preparatory work described above. Reinforcement was carried out using the MAPEI FRG System technology, which consists of the use of two-component cement mortar Planitop HDM Maxi and alkali-resistant glass fiber grid Mapegrid G120, which is embedded in the mass of the mortar. This system has shown its effectiveness during laboratory tests on strengthening brick columns (conducted on the basis of Lviv Polytechnic University in 2018) [6, 7, 9] and in practice.



**Fig. 6.** Scheme of the MAPEI FRG System amplification system

The installation of this reinforcement system does not require special equipment and mechanisms, the additional weight of the reinforcement system is 21 kg per 1 sq. m surface, while “cold bridges” are not formed, which has a positive effect on the energy efficiency of the building.

#### **Installation of the first stage of the MAPEI FRG SYSTEM.**

Before starting the reinforcement, it is necessary to drill holes for the anchor fixation of the edges, with a step of approximately three holes per 2 rows of reinforcement, with a diameter of 10 mm, and insert a plug (for example, an armature) into them.



**Fig. 7.** Marking the column, making holes and inserting “plugs” into them

Apply the first layer of Planitop HDM Maxi (two-component fiber-reinforced solution with pozzolanic reaction) with a thickness of about 5 mm.

While the solution is still “fresh”, lay the grid with Mapegrid G120, pressing it with a flat spatula to ensure good adhesion to the solution. Adjacent longitudinal / transverse strips of MAPEGRID G120 at the connection points should have an intersection of at least 15 cm. In places where there are cracks on the base, we recommend installing a double reinforcing layer as additional protection.



**Fig. 8.** Sequential application of Planitop HDM Maxi, Mapegrid grid, Planitop HDM Maxi smoothing



**Fig. 9.** General view of columns with the first layer of Mapei FRG System applied

### **Production of carbon anchors for MAPEI FRG SYSTEM fixation.**

Composite anchors based on carbon or glass fiber cord impregnated with epoxy solution are arranged in the MAPEI FRG System to fix vertical and horizontal mesh intersections. Preparation of MapeWrap C Fiocco cords. Pull the cord from a special hole in the upper part of the package, and, using scissors, cut off a piece of the cord with a length that depends on the thickness of the structure to be reinforced, but not less than 400 mm. From one end of the cord (which must be impregnated with resin), pull (do not cut!) the net to the other end (the one that will not be impregnated). In this way, expose the fibers, dip them in MapeWrap 31 resin and impregnate them.

After impregnating the cord, remove excess resin with light pressure with your fingers (be sure to use protective rubber gloves!). Next, return the protective net to the impregnated fibers. To create better adhesion, sprinkle the impregnated cord fragments with quartz sand and leave for 24 hours until the glue hardens.

### **Installation of carbon anchors for MAPEI FRG SYSTEM fixation.**

After preparing the MapeWrap C Fiocco cords, drill holes in the design locations with a depth of about 200 mm. The diameter of the hole should be one size larger than the diameter of the cord (from 6 to 12 mm). The pitch of the anchor holes must be pre-calculated.

Clean the holes from dirt and dust with an air compressor.



**Fig. 10.** Blowing holes from dust, filling the hole with a chemical anchor

Before starting work, MapeWrap Primer1 primer is applied to the hole using a brush. While the soil is still fresh (approximately 30-40 minutes after application), use a construction gun to inject the ready-made Mapefix VE SF anchoring solution into the hole.

After filling the hole with adhesive solution, insert MapeWrap C Fiocco into the hole with the hardened part (Fig. 11). Apply MapeWrap Primer 1 epoxy primer around the hole. Apply a layer of Adesilex PG1 epoxy solution 1-1.5 mm thick over the fresh primer layer, distribute the fibers in the form of a fan (in a circle around the hole).



**Fig. 11.** General view of the anchoring system

Next, a finishing layer of Planitop HDM Maxi with a thickness of approximately 4-5 mm is applied.



**Fig. 12.** General view of reinforced columns on the third floor

### 3 Conclusions

According to the conducted theoretical studies [6, 7, 9], the application of the reinforcement system using composite materials Mapei FRG System is currently an effective way of restoring the load-bearing capacity of brick structures, and its application in practice has proven its effectiveness according to the following criteria:

As soon as possible.

1. With a minimum additional load of structures (the weight of the system is approximately 21 kg/sq. m).
2. Without the use of large-sized equipment and lifting mechanisms.
3. Without additional “bridges” of cold, without disturbing the thermal insulation of the building.
4. The linear expansion of the materials of the reinforcement system is like the linear expansion of the structure itself, thanks to which the system works simultaneously with the base and does not require additional anchoring.

5. Unlike repair work during sheathing with steel plates, there is no problem of corrosion when using the reinforcement system.
6. The system meets the requirements of CNR DT 200/2004: “Instructions for the design, implementation and control of stationary reinforcement systems using fiber-reinforced composites”.

However, it should be understood that the choice of restoration and reinforcement technology must be considered separately in each case, because there are many different factors that affect the choice of technology and methods of reinforcement, the choice of materials and other factors that can affect the final result.

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