

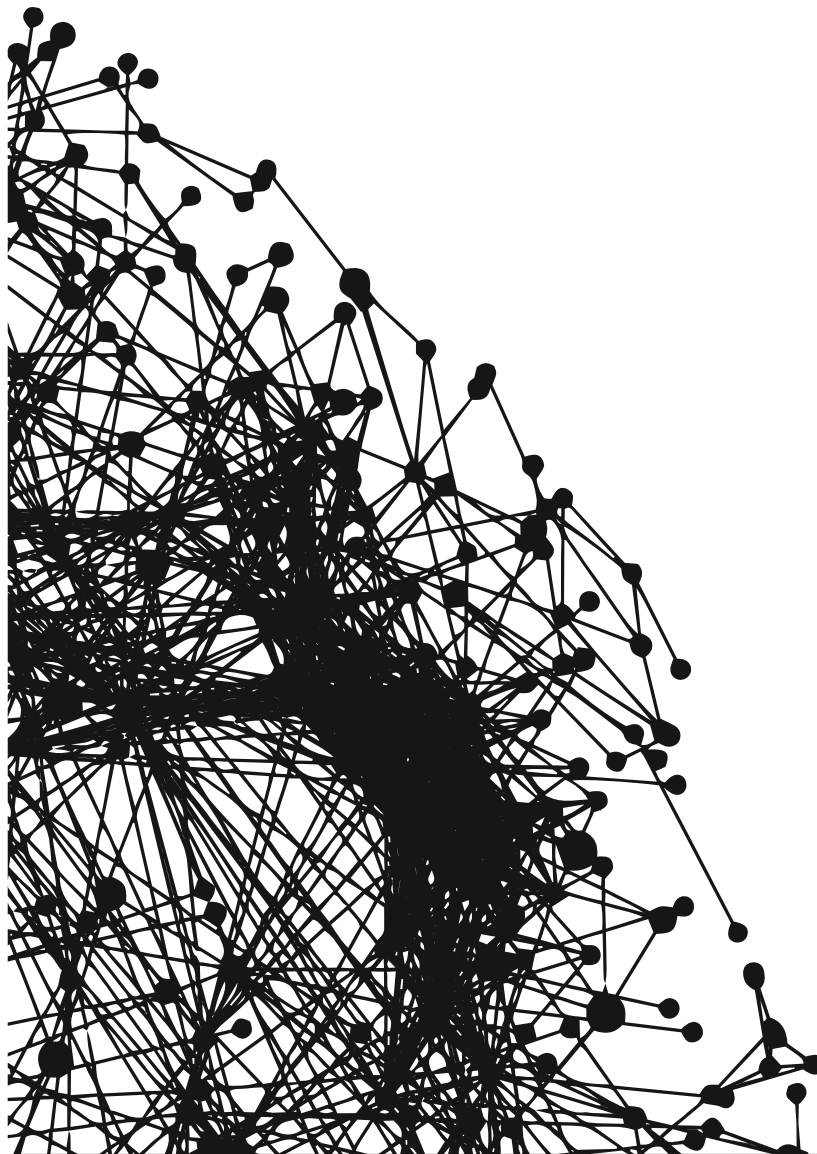
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Eva Vaništa Lazarević, Aleksandra Đukić,
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MODERN STRENGTHENING METHODS FOR MASONRY WALLS

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ABSTRACT

The reconstruction and rehabilitation of architectural structures require the application of modern strengthening methods of masonry walls in order to preserve them and increase their bearing capacity. These modern methods of masonry wall strengthening imply the injection (grouting) and strengthening method of applying carbon-fiber mesh. Cracks and holes in masonry walls are seen as a major structural problem of reconstruction. The application of modern grouting is the solution to this problem. The grouting technology causes monolythisation of masonry walls. Mortar injection process fills the cracks and holes caused by external influence or rinsing the existing bonds, as well as the holes created during the process of building those walls. Types of mortar used for wall strengthening and reconstruction are cement mortar, cementless mortar and ready-mixed mortar, depending on a crack itself, its type and position and material of the masonry wall. Carbon-fiber cladding strengthens the masonry walls preparing them for horizontal pressure. Mesh and mortar used for attaching the mesh to masonry walls are specially made to strengthen the masonry walls and are different from carbon-fiber meshes used for concrete wall strengthening. These procedures are the most commonly used modern methods and technical solutions in the field of reconstruction of architectural structures. They are performed in order to provide protection and resistance to horizontal pressure.

Key words: masonry wall strengthening, injection, mortar injection, carbon-fiber mesh for strengthening of masonry walls

INTRODUCTION

Various methods of masonry wall strengthening are applied in the field of reconstruction and rehabilitation of architectural structures. This paper presents the methods that can be included in the process of reconstruction and rehabilitation.

Also, the papers presents the procedures that keep the original structural system of architectural objects but also provide the best possible solution that do not damage potential fresco paintings on the walls.

The following methods can be applied in the process of strengthening of masonry walls:

- Injection, crack and depression filling,
- Wall bracing (braced structures) for floor structures,
- The application AB coating system for strengthening the existing walls,
- Strengthening of masonry walls by applying special carbon-fiber mesh connected to the walls with special mortars,
- Strengthening of masonry walls by performing the cutting of new AB or steel elements,
- Strengthening of walls by installing steel weights into the existing or subsequently formed wall cavities

INJECTION

The presence of crack and holes in masonry walls is a major problem. The application of injection method represents one of the keys to solving this problem and it leads to monolithisation of old walls made of brick or stone. This method strengthens masonry walls and prepares them to receive and resist horizontal pressure due to earthquake. Methods of injection grouting fill both cracks and holes caused by external conditions: earthquake, wind, soil settlement, material deterioration, structural element collapse and centuries-old rinsing of the existing bonds. Sometimes, wall depressions are as old as a building itself, since some depressions appear during the process of construction.

Types of mortar used for wall strengthening and reconstruction are cement mortar, cementless mortar and ready-mixed mortar, depending on a crack itself, its type and position and material of the masonry wall. The presence of fresco paintings on the wall involved in the method of injection requires some special protection measures and directly influences the selection of mortar. When it comes to strengthening of the masonry walls made of brick or stone – the walls that used to have wooden construction (santrač) to resist tension force, it is also possible to apply the method of injection to the existing holes and install reinforcement bars.

When it comes to injecting the walls of buildings of great importance and cultural value, it is necessary to select a proper mixture for each specific case. Apart from necessary measures of preventive and physical protection, the application of the injection method requires enormous experience and knowledge of all the engineers and conservators taking part in the process of reconstruction, as well as the precious experience and skills of the craftsmen involved in the process of carrying out these procedures.

Injection methods for masonry walls

The method of injecting a masonry wall includes the following steps:

- Defining the composition of existing walls,
- Preparing the surface of walls, flush mortar jointing or pointing,
- Installing the pipes for grouting mixture injecting,
- Making the injection mixture,
- Injecting the mixture,
- Removing the injection pipes and repairing the wall surface.

In order to determine the adequate measure of mortar that is to be applied to a particular wall, it is necessary to define the composition of that wall and apply a suitable mortar injection mixture, taking into consideration the composition and quality of the placed material. The quality of the injection mortar that is to be applied has to be better than the quality of the existing mortar but still not much better than the mortar already used for the existing wall.

As for the injection procedure, it is necessary to pay attention to the type of mortar used for wall strengthening – it should be cement-lime mortar (i.e. the chosen mortar should contain at least a small quantity of lime). When the injection procedure is carried out next to steel reinforcement, mortar injection must not contain lime. Elasticity of mortar is obtained by adding a small or larger quantity of lime, just like old builders used to do. Or, when it comes to pure cement mortars, it can be performed by some additives. The next step in preparing the injection procedure implies the face of a wall and required interventions. First of all, it is necessary to fix the face of the wall and then perform the procedures of pointing and flush mortar jointing, depending on the previous method of wall face construction, and then install the injection pipes into vertical cracks. If a face of a wall does not contain any cracks, it is necessary to find the wall cavities (vertical cracks on the walls, former weights or wooden construction – santrač, etc.) in order to locate the holes into which the injection pipes are to be installed.

There are some non-invasive methods of wall cavity positioning (geo-radar analysis, thermo-visual camera, etc).

If it is not possible to locate any cavity, the injection pipes are placed into previously drilled holes in a wall, regular raster arrangement of 80/80 to 100/100 cm, at the very junction between the blocks of stone or brick. Injection pipes are made of a standard garden hose.

When the process of injection is carried out through injection pipes, it is important to rinse the interior pipe wall with water or clear (purge) the pipes with compressed air, if possible, and only then should the procedure of injection start, from bottom to top. A special under-pressure machine is used for injecting the mixture into pipes. Excessive over-pressure might destroy the structure of walls. Cavity filling is carried out horizontally until the injection mixture – mortar injection comes out from the adjacent pipe. It is of vital importance to have the pressure under control, especially when dealing with fresco paintings. Excessive pressure might cause the existing

mortar to come off the wall surface damaging the paintings on the wall. These are the places where the injection should be performed by using smaller pressure, maximum 0.3 bars of overpressure.

Injection mortars

The injection composition – injection mortar, depends on the location of injection itself as well as on the quality of material used for wall construction.

It is recommended that the injection mixtures are made in accordance with the volumetric ratio of material, which ensures a simple mix proportion at the construction site (Figure 1.).

The injection mixtures can be formed using a binder made of natural pocalan and lime, lime-based binder, lime and cement-based binder or it can be a pure cement injection mixture. Apart from binders, these injection mixtures contain an aggregate as well as a certain amount of water to achieve desired consistency of the injection mixture (yogurt consistency).

Cementless injection mortar is applied to the walls covered with fresco paintings. Cementless mortars use natural pocalan as binders – volcanic ash (Naples pocalan, Santorini soil) and lime.

The cement-based injections without lime are only applied to the area that contained wooden construction – santrač, which was burned or rotted, and standard steel reinforcement bars were placed instead. The cement-based injections without lime are also applied to those places where steel profiles were installed in order to provide additional wall strengthening. If the method of wall strengthening is ensured by stainless steel reinforcement, cement and lime-based injections can be applied.



Figure 1. Mortar mixers for making injection mortar: a) standard rotating drum mixer and volumetric measure for determining the ratio of material, b) planetary mortar mixer without a rotating drum

In addition to injection mixtures that are prepared at construction sites, there are also pre-blended mixtures such as Mape Antique F21 (produced by MAPEI). This injection mixture is specially designed for the walls covered by fresco painting and contains aggregate, lime and eco-poculan.

Injection equipment

Injection mortar is injected into walls and this procedure is carried out using two types of equipment:

- a) Equipment with a closed drum containing a mixer; the equipment is hermetically closed after pouring the injection mixture into the drum; this type of equipment is connected to standard compressors (Figure 3a.)
- b) Injection machine is a modification of a machine-pump used for mortar transport and machine plastering using spiral rotors, without additional compressors. This injection machine consists of a three-way valve nozzle used for continuing the procedure of mortar passing through a hose and coming back to the machine tank at the moment when the wall injection procedure stops. In this way, mortar recirculation reduces the possibility of clogging a hose caused by the termination of wall injecting. (Figure 2b and Figure 3).



Figure 2. Injection equipment: a. Equipment with a standard closed drum, c. Injection machine with a spiral rotor

Apart from the workmen taking part in mortar preparing procedures and mortar injecting in the walls, it is also necessary to hire a great number of other workers in order to watch and control the wall in the process of injection. This is a very important part of the whole process, since the injection mixtures can easily pass through the wall and spill at a great distance (even greater than 10m) from the very place of mortar injecting (Figure 3).



Figure 3. Injecting the injection mixture into a wall, using a nuzzle consisting of a manometer and a three-way valve that is used for returning unused mortar injection into a tank – mortar injection recirculation

STRENGTHENING OF WALLS USING CARBON-FIBER MESH

Strengthening of masonry walls using carbon-fiber meshes connected – glued to the walls by special types of mortar, reinforces the walls enabling them to receive shearing-horizontal forces in the direction of walls. In comparison to all other methods used for cladding, this very method is a reversible one (it can be easily replaced), when compared to the methods of strengthening of walls using new reinforcement concrete cladding or cutting or installing new reinforcement concrete or steel elements. This cladding is fire-resistant in relation to the methods of attaching carbon meshes to a construction using the epoxy resin. One of the advantages of using carbon meshes glued to masonry walls by special types of mortar is the application of mortars and eco-poculan and lime-based binders containing no soluble salts. These types of mortar do not have any negative and harmful effects on fresco paintings placed on the wall included in the strengthening procedures. The application of special mortar types enables the adhesion to various substrates.

Another advantage of this method is a rather low weight that is added to masonry walls in the process of their structural reinforcement.

Previous methods included epoxy resin for bonding a carbon mesh to various substrates. The structures reinforced in this way, using the epoxy resin, had to be provided with additional protection in order to achieve water-resistant condition.



Figure 4. The phases of strengthening of walls using carbon meshes

Strengthening can be performed by applying the cladding of masonry walls on both sides or one side only; however, a special attention must be paid to further anchoring of the existing masonry wall. The strengthening method of masonry or brick masonry walls is performed by bonding special meshes containing adequate mortars. (Figure 5). The wall in the process of strengthening must be thoroughly washed under high pressure in order to remove any potential grease. As soon as it has been carried out, leveling mortar is applied to that wall. A type of mortar to be applied depends on the required mortar thickness needed to achieve a flat wall surface. Once the leveling mortar has been applied to a wall, the mortar for carbon mesh adhesion is applied over the wall. Then, a carbon mesh is placed vertically, taking into consideration a necessary flap. When the carbon mesh is covered by adhesive, a new layer of mortar is added, followed by a new layer of carbon mesh to create a 45° angle compared to the previous layer, again with a proper flap. Over the carbon mesh covered by adhesive a new layer of mortar is applied, followed by a carbon mesh to create a 90° angle compared to the previous carbon mesh layer. If necessary, the layer of mortar is covered with additional layers of carbon meshes and the whole procedure is repeated.

Additional anchoring of carbon meshes used for a base can be performed in the following way. Drill some holes in the wall, diameter $\varnothing 40$ mm with a raster (50 cm distance in a staggered row, rows placed at 50cm and the next one is 25 cm staggered). These drilled holes are to be thoroughly blown out by compressors, and carbon mesh is to be rolled in a way that there is approximately 20 to 25cm out of a wall face. A part outside of the wall is to be cut in five to six parts in order to make a shape with the entire area glued to the wall. Both drilled holes and their surrounding area is to be adequately soaked. The mesh is to be glued to the wall using a suitable

mortar type, and the same type of mortar is to be applied for filling in a hole in the wall.

CONCLUSION

The methods of injection and strengthening of masonry walls using carbon meshes and adequate mortar types enable the existing reinforced vertical structural elements to receive gravitational force and horizontal seismic forces.

The application of modern methods of strengthening masonry walls in the field of reconstruction and rehabilitation of architectural structures increases their bearing capacity and durability.

These methods are the most common modern technical solutions in the field of repair and reconstruction of architectural structures, meant for providing their preservation and protection.

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