EXPERIMENTAL CONSIDERATIONS REGARDING BRICK MASONRY STRUCTURAL WALLS CONSOLIDATING

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Abstract: This paper aims at giving a succinct presentation of some aspects regarding the advantages of the brick masonry walls, which makes their consolidation necessary and realistic in case of damage. Secondly, various solutions are presented for strengthening, with emphasis on those made of micro-concrete reinforced with thin wire mesh, and also called “ferrocement”, a solution verified by practice in the INCERC Cluj-Napoca laboratory.

Keywords: Structure measurement, ferrocement, micro-concrete, consolidation

1. GENERAL CONSIDERATIONS
The diversification of strengthening procedures for structures of resistance is very important in view of the large variety of construction and their use.

From this perspective, we consider useful to present a solution for consolidation using micro-concrete reinforced with thin wire mesh, known as "ferocement”, method verified by measurements, which, as will be seen, can be applied successfully to the strengthening of brick masonry structures.

The most widely used structural walls have been and will probably be those of brick masonry, as they present a number of advantages, among which we would like to mention:

- They are lasting: well built and appropriately preserved masonry can last for a few hundred years;
- They have a good thermic insulation: they have reduced thermic conductivity coefficients \( \lambda = 0.80 \text{ W/mK} \);
- Ensure good sound proofing;
- Ensure a good respiration of the rooms;
- Have a good fire resistance;

For different reasons, brick masonry undergoes deteriorations and degradations, among which cracks and fissures are the most frequent. Quite often, a crack appeared in the plaster hides a deep crack in the brick masonry.

Regarded from this perspective, the damage of the masonry can be divided into two categories:
- marked cracks, which indicate massive masonry dislocations;
- small but numerous cracks or fissures, which show a degradation of the masonry.

2. CAUSES FOR MASONRY DETERIORATION
Generally, the causes which produce the deterioration or degradation of masonry are:

- the ageing of the material as time goes by (the bricks and mortar);
- the lack of maintenance of the building and the condensation phenomenon;
- the degradation of the foundation ground as a result of the infiltration of pluvial water, of the wastes from supply or sewerage installations, of the increase in the level of the water layer or the changes in the routes triggered by new buildings;
- the seismic action;
- other extraordinary actions such as explosions, fires etc.

3. THE CONCEPTION AND THE GENERAL CONSOLIDATION PRINCIPLES
Generally, the consolidation conception of masonry buildings has to consider the following aspects:

- To eliminate the causes which produce material degradation;
- To avoid changes of the structural system;
- To improve the transmission of loads to foundations;
- To bind the adjacent vertical elements;
- To put together the vertical structural elements.

The consolidation of masonry structures can be accomplished through:

- rebuilding dislocated masonry;
- partial reinforcement with concrete;
- injecting and flating cracks and fissures;
- stitching fissures using steel cramps;
coating the walls with mortar, concrete or composite materials;
• bordering the gaps;
• binding corner areas;
• introducing ties and/or metal fishplates;
• placing horizontal and vertical elements made of reinforced concrete.

The consolidation concept of the structural system may require the combination of the afore-mentioned procedures, according to the causes that triggered the damage, the yielding mechanism and the condition of the building, in particular.

When accomplishing any rehabilitation work for brick masonry structures, a paramount stage is represented by the preparation of the masonry, which consists of the following:
• removing the existing plaster;
• deepening the empty spaces for 15-20mm;
• removing the non-adherent material by scrubbing using a wire brush until the pores of the masonry stone are open;
• using compressed air to blow the cleaned surfaces with a view to removing the dust.

4. COATING CONSOLIDATION

In what follows, we will refer to the solution of consolidating by means of coating the walls. This solution is indicated for old structures which are strongly deteriorated and which have a significantly diminished portant capacity of the structural walls.

In practice, there are different solutions for consolidating masonry walls by means of coating. Thus, there are coatings on one or both sides of the structural walls, using cement or concrete-based mortar, the reinforcement being accomplished by means of welded nets made of 4-6mm thick wire having meshes of 100-200mm, as well as using independent mesh-bound bars 6-8mm thick, polymeric grates or meshes made of thin wire, 1-2mm thick, with rectangular or hexagonal spaces between bars, 20-30mm thick, placed on one or several layers in the thickness of the coating layer.

Each of these solutions presents a series of advantages and disadvantages, as well as numerous peculiarities.

While research has been conducted and concrete solutions have been offered in the case of consolidating walls using thick welded mesh or using polymeric grates, little is known about the consolidation using micro-concrete reinforced with thin mesh, called ferrocement [1], [2], [3], [4], [5]. That is why in what follows we aim to present some aspects which should give emphasis to this method, based on the trials which were accomplished on experimental models at INCERC Cluj-Napoca. The masonry walls used by INCERC Cluj Napoca for obtaining information with a view to improving the calculation methods for masonry structures under seismic actions have been used in our research to check the efficiency of the consolidation by coating with ferrocement and to establish connections between the theoretical and the experimental calculation model.

The masonry walls have been built in two ways: from 240x115x63mm filled ceramic bricks and GVP 290x240x138mm ceramic bricks with vertical voids. The masonry mortar was M50. In both cases, an outline framing of the masonry has been accomplished with 24x10cm pillars and 24x20cm belts made of concrete class Be10 (B150), according to the standard P2-85 [6].

The vertical reinforcement with pillars was 4ф8 PC52, the superior belt being also embedded in the foundation. The transversal reinforcement of the pillars was accomplished by means of black wire bars f55mm, having a transversal reinforcement percentage of 0.157%. The final dimensions of the masonry panels were: h=190cm (including the 20cm belt), l=180cm and the thickness of 24cm.

The wall models have been submitted to cyclical lateral trials in the presence of a constant vertical load which produced a 0.4Mpa axial effort at their foot (including its own weight).

As a result of the trials performed between 2001 and 2002, it was found that the panels made of masonry confined with pillars surrendered under the sliding shear force through on the route of inclined fissures and the shearing of the pillars.

In order to consolidate the respective walls, which were initially tried until they broke down, the following technology was used:
- the affected surfaces were polished with a chisel in order to remove the deteriorated material (exfoliated, broken, etc.);
- the surface was cleaned using a water jet and a wire brush to remove the small pieces of material and the dust;
- on the clean and rugged surface, nails were hammered in the mortar empty spaces. The distance between the nails was 20…25cm, and the remaining free length of 10…15mm. at the same time, plastic disks were fitted, playing as distance pieces;
- a layer of mixture was applied on the surface, made of cement milk;
- two layers of zinc-coated steel wire mesh were positioned, with a diameter of 1mm and the distance between the bars of 10x10mm. In order to fix the meshes, the previously positioned nails were used;
- the mortar was applied by an average 3,5 cm injection with concrete, the covering layer being at least of 0,5cm; the mortar was prepared according to the following recipe: cement Pa40 - 500kg/mc, sand 0-3mm 1700 kg/mc, water 250kg/mc.

From the trials on the test pieces made of this mortar, the following values resulted regarding the resistance to compression: 7,5N/mm² after 7 days and
39\text{N/mm}^2\text{ after }28 \text{ days. The values for the stretching resistance from bending to were }1,12\text{N/mm}^2\text{ after }7 \text{ days and }7,75\text{N/mm}^2\text{ after }28 \text{ days.}

- the sides of the element were finished off through the application of a polishing plaster coat and of a white painting which makes fissures more visible.

The trial of the consolidated elements was accomplished in the same conditions as the unconsolidated ones, respectively by applying alternating lateral forces by means of hydraulic jack in the presence of a vertical force which created an effort of 0,4\text{N/mm}^2\text{ at the foot of the masonry panel. The two layers of concrete-injected mortar together with the broken masonry formed such a rigid unitary whole that, under lateral forces equal with those which made unconsolidated panels to break down, respectively 224\text{KN}, the panel rotated as a rigid solid in rapport with the contact point between the wall and the foundation, without fissures to be produced on the sides of the panel.

In order to mobilize the concrete-injected mortar, it was necessary to block the rotation by introducing an additional tie bar placed at the edge of the consolidated masonry panel.

In this new situation, the alternating forces were applied in an increasing pace, starting with the value of 40\text{KN}, in stages of 40kN. The breaking down took place when the value of the lateral force was around 230\text{KN}, at the VI cycle, when the mortar cover detached from the masonry.

Figures 1 and 2 show the diagrams F- $\Delta$ (force - movement) by load cycles for the unconsolidated masonry panel, respectively for the same panel, which was meanwhile coat consolidated.

Fig. 3. The fissures for the unconsolidated masonry element

Fig. 4. The fissures for the consolidated masonry element

Figures 3 and 4 show the fissures for the unconsolidated panel, respectively for the same consolidated panel during the breaking stage. Figures 5 and 6 show the trial scheme and the way the element under trial was equipped with measuring apparatus.

Fig. 5. Trial scheme
In fig. 7 (photo), we presented the panel which underwent the trial using the above mentioned equipment. The quality of ferrocement to have a very good resistance to fissuring gives it a great advantage over the use of reinforced concrete. The increased resistance to fissuring, combined with the easiness of applying it, as well as its relatively small weight and the reduced cost, make ferrocement an ideal system for rehabilitating structures.

The main objective envisaged for the consolidation and rehabilitation of masonry structures is represented by the recovery of their portant capacity with as reasonable costs as possible. From the numerous reparation and rehabilitation programs for structures which have used ferrocement, H. Ahmed and L.R. Austriaco [5] underline the following aspects:

- good behavior as regards fissuring;
- capacity to improve certain mechanical peculiarities of consolidated structures;
- the accomplished consolidations allow changes and subsequent reparations;
- the relatively reduced weight resulted from the consolidation systems does not require changes in the structure support system;
- facility to oppose to temperature changes;
- facility to allow good water proofing, without special treatments;
- easiness to purchase necessary materials;
- does not require special technological equipment;
- flexibility to subsequent changes;
- possibility not to alter the architectural concept of the structure and, implicitly, of the building as a result of the consolidation.

5. CONCLUSIONS

As a result of the mentioned trials, the following conclusions can be drawn.

- by applying coat consolidation on 2 sides, using cement mortar and thick wire mesh, the element regained the initial portant capacity (slightly enhanced);
- from the analysis of the diagrams F- Δ, it was found that there was an increase in the rigidity of the coat-consolidated element, despite the fact that it had practically been broken in the initial trial (when it was unconsolidated).
- from the analysis of the fissures, it was found that, while unconsolidated masonry panels exhibit great fissures, between 10 and 30mm, in the case of consolidated panels these fissures are much smaller, respectively between 0.05 and 0.5mm.

References:
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