

TECHNICAL UNIVERSITY OF CIVIL ENGINEERING OF BUCHAREST

UTCB DOCTORAL SCHOOL

**Doctoral thesis**  
**The seismic resilience of interwar buildings**

**Scientific report II**

**Original experimental research, carried out through  
European scientific programs, at the turn of the centuries XX  
- XXI**

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## CONTENTS

|                                                                                                                                              |    |
|----------------------------------------------------------------------------------------------------------------------------------------------|----|
| Chapter 1. INTRODUCTION.....                                                                                                                 | 3  |
| Chapter 2. The Euroquake Project, JRC-ISPRA, Varese, Italy .....                                                                             | 5  |
| 1. General data .....                                                                                                                        | 5  |
| 2. 3D model in natural size without gaps .....                                                                                               | 6  |
| 3. 3D model in natural size with gaps.....                                                                                                   | 7  |
| Chapter 3. The Ecoleader Project, ISMES, Bergamo, Italy .....                                                                                | 9  |
| 1. General data .....                                                                                                                        | 9  |
| 2. 3D model of a patrimonial building made of solid brick masonry with lime mortar in the unconfined variant .....                           | 9  |
| 3. 3D model of a patrimonial building made of solid brick masonry with lime mortar in the confined with polymeric grids variant .....        | 11 |
| 4. 3D model of a patrimonial building made of hollow brick masonry and lime-cement mortar in the unconfined variant.....                     | 13 |
| 5. 3D model of a patrimonial building made of hollow brick masonry with lime-cement mortar in the confined with polymeric grids variant..... | 15 |
| Chapter 4. The ASTRA polygon, Ploiești.....                                                                                                  | 17 |
| 1. General data .....                                                                                                                        | 17 |
| 2. The results of the experiment.....                                                                                                        | 20 |
| Chapter 5. INCERC, Iași, Romania .....                                                                                                       | 20 |
| 1. General data .....                                                                                                                        | 20 |
| 2. The results of the experiment.....                                                                                                        | 21 |
| Chapter 6. ISMES, Bergamo, Italy .....                                                                                                       | 22 |
| 1. General data .....                                                                                                                        | 22 |
| 2. The results of the experiment.....                                                                                                        | 23 |
| Chapter 7. Comparative table .....                                                                                                           | 24 |
| 1. Presentation of the table .....                                                                                                           | 24 |
| 2. Brief commentary .....                                                                                                                    | 25 |
| Chapter 8. CONCLUSION .....                                                                                                                  | 27 |
| BIBLIOGRAPHY .....                                                                                                                           | 27 |
| BIBLIOGRAPHY – INTERNET .....                                                                                                                | 27 |

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|                          |    |
|--------------------------|----|
| LISTING OF FIGURES ..... | 28 |
| LISTING OF TABLES.....   | 29 |

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## Chapter 1. INTRODUCTION

The experience of the 1977 earthquake brought about real progress in the domain of construction. Subsequent studies have led to a better understanding of the characteristics of seismic movements in Romania. Design methods and building conformation concepts have also evolved significantly.

On the 31<sup>st</sup> of August 1986, an earthquake took place, its seismic source being in the Vrancea area. This earthquake had a magnitude of 7.1 degrees on the Richter scale and was 131.4 km deep. [9]

The earthquake could be felt in 8 countries, damaging a great part of south-eastern Europe. The most affected region was Focșani-Bârlad, where its intensity was VIII degrees on the Mercalli scale, leading to, for example, the collapse of a church. In Khisinev, 4 blocks of flats collapsed, resulting in approximatively 100 victims. Within the floodplain of the Prut river, the ground collapsed and craters appeared. Also, the earthquake injured 558 people and either destroyed or damaged 55.000 households. Its intensity was different depending on the areas where the earthquake was perceived. Therefore, in Bucharest and in the north of Bulgaria, it had the intensity of VII, in Skopje, the intensity of V, in Simferopol, Kiev, The Sovietic Union and in Belgrad, the intensity of IV, while in Moskow, Titograd and areas from Yugoslavia, the intensity was of III. [9]

On the 30<sup>th</sup>/31<sup>st</sup> of May 1990, three earthquakes took place within the Vrancea area, being 89 km deep and having a magnitude of 6.9 deegres on the Richter scale. In Romania, 8 people died and 362 were injured. Out of those, 100 were seriously hurt, while 262 had minor injuries. In the Moldavian SSR, 4 people died and dozens of people were injured. [9]

These events have brought to the forefront the need for further research in the field of construction. Major advances have been made for concrete structures, whereas in the case of load-bearing masonry, more studying has to be done. It was also considered necessary for heritage buildings to be the subject of research.

Therefore, in the time period between 1980 and 2000, several tests on masonry models were carried out by the Iași branch of INCERC. The events of 1989 led to more friendly relations between Romania and the European Union. In this context, a step forward was made in the direction of collaborative relations, including those in the field of construction research.

The study of coating with polymeric grids was considered as a modern solution for consolidating old buildings with load-bearings masonry, and not only. The experiments

carried out at JRC-ISPRA, Varese, Italy, as well as the Ecoleader Project, ISMES, Bergamo, Italy are taken into consideration.

This report contains experimental studies featuring comparisons between 2D, 3D and natural scale models of load-bearing masonry, with solid bricks and lime mortar or hollow bricks and cement mortar. The models were subjected to seismic stress, the shock of a pendulum, or to the shock of an explosion.

All the models subjected to the experiment emphasize the reinforcement with polymeric grids. According to Laundau's Theory of Dislocation, the vertical joints between the bricks represent geometric imperfections, areas at the level of which there are concentrations of effort in the case of short-term actions. These areas are at the origin of the dislocations generated by the  $\sigma$  unitary efforts that reach the level of strength of the material. Given its regular geometry and tensile strength, the grid will take over the efforts from the masonry and redistribute them evenly within the masonry mass, with the help of the mortar. [4]

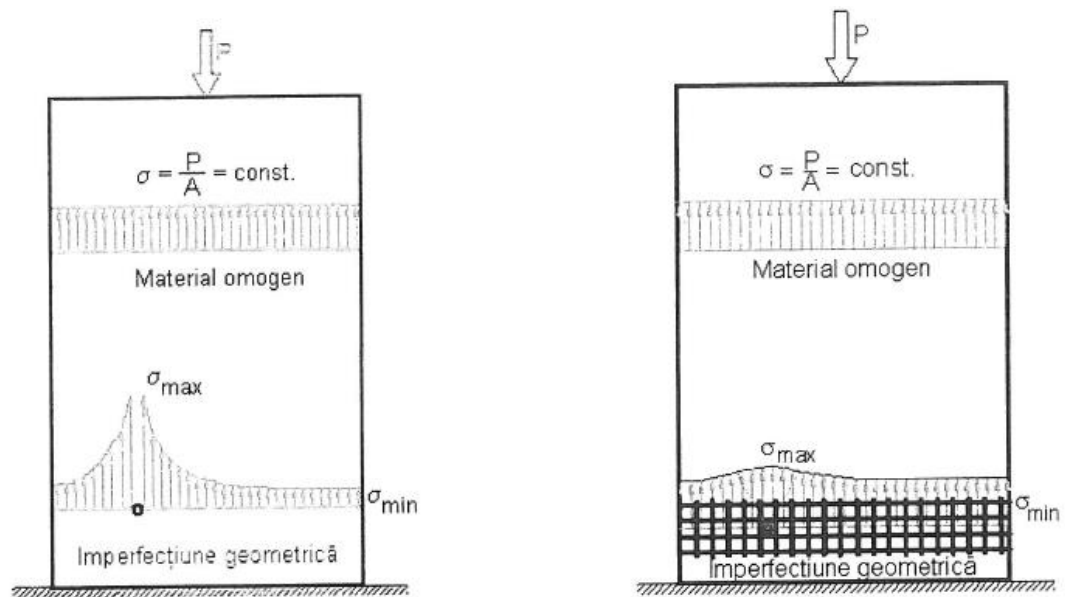


Fig. 1.1. The  $\sigma$  efforts subjected to a force, highlighting the geometric imperfections, on the left and the attenuation of the efforts with the help of the grids, on the right [4]

## Chapter 2. The Euroquake Project, JRC-ISPRA, Varese, Italy

### 1. General data

Within the Euroquake project, tests on 4 types of masonry were carried out at the Laboratory for Construction Safety from JRC – ISPRA, Varese, Italy. [4]

Tests were performed on 4 panels of brick masonry, two of them being made of simple masonry, and the other two being reinforced with RG30 polymeric grids. The reinforcement was made at the level of the joints, each third joint being reinforced, as well as by confining it through coating. The used bricks were ones with vertical gaps and the mortar was lime-cement. The vertical gaps are 42% perforated and are not recommended for use in seismic areas, but they were used precisely to demonstrate their unfavourable behaviour. [4]

The 4 panels were organized for testing purposes into two simple masonry panels, without gaping, and into two panels with two unequal and asymmetrical gaps, being completed with two metallic space frames. The dimensions of a panel were 4.60 x 2.60 m. Therefore, 2 3D models of a natural size were obtained, one with gaping and the other one with gaping. [4]

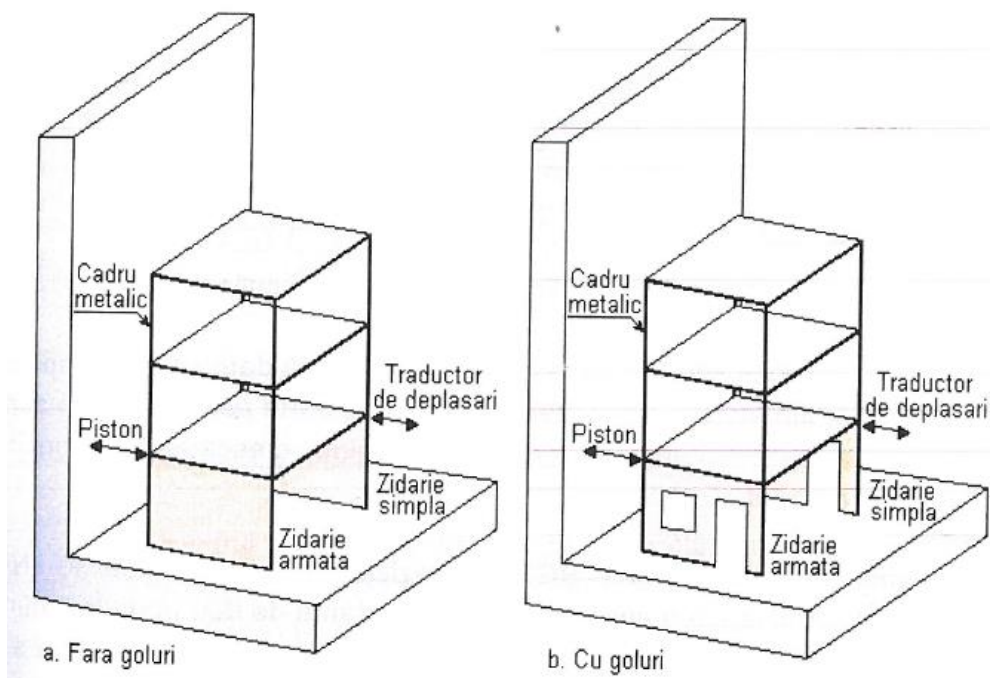


Fig. 2.1.1. The two 3D models, one with gaping and the other one without gaping [4]

The loading system consisted of inducement above the first level of precise displacements by means of pistons, one being placed in front of the simple wall, and the other one being placed in front of the reinforced wall. [4]

## 2. 3D model in natural size without gaps

The behaviour of the 3D model without gaping in natural size was highlighted by the hysteresis curves corresponding to this model. Thus, the response of the simple masonry panel is represented by the blue colour, whereas the response of the reinforced masonry panel is represented by the red colour (Fig. 2.2.1). [4]

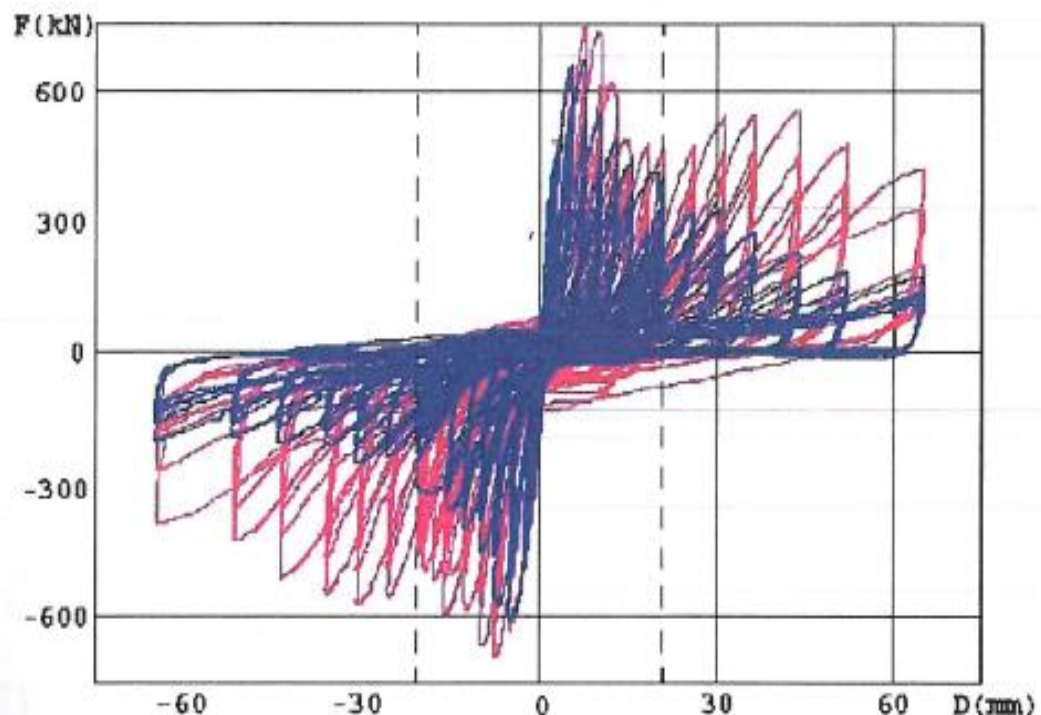


Fig. 2.2.1. The hysteresis curve for the 3D model without gaping [4]

Hysteresis curves highlight the following aspects. The behaviour of the simple masonry panel is classical. Until the maximum strength is reached, the behaviour is quasi-elastic, with a cyclic degradation of the strength between the first and the second cycle. The point of maximum strength is followed by a phase of rapid degradation, characterised by crushing the bricks at the corners and the bricks at the centre of the panel being fissured. [4]

The reinforced masonry panel remained intact. The initial strength has increased insignificantly compared to that of the first panel, but the obvious difference is a much better behaviour during the loading cycles. Degradation of the strength was very limited.

It can be seen that, in this case, the reinforcement with polymeric grids does not bring a contribution to the rigidity of the structure, while the contribution to the strength of it is insignificant. Instead, it significantly improves the behaviour of the masonry panel when it comes to the cyclic action.

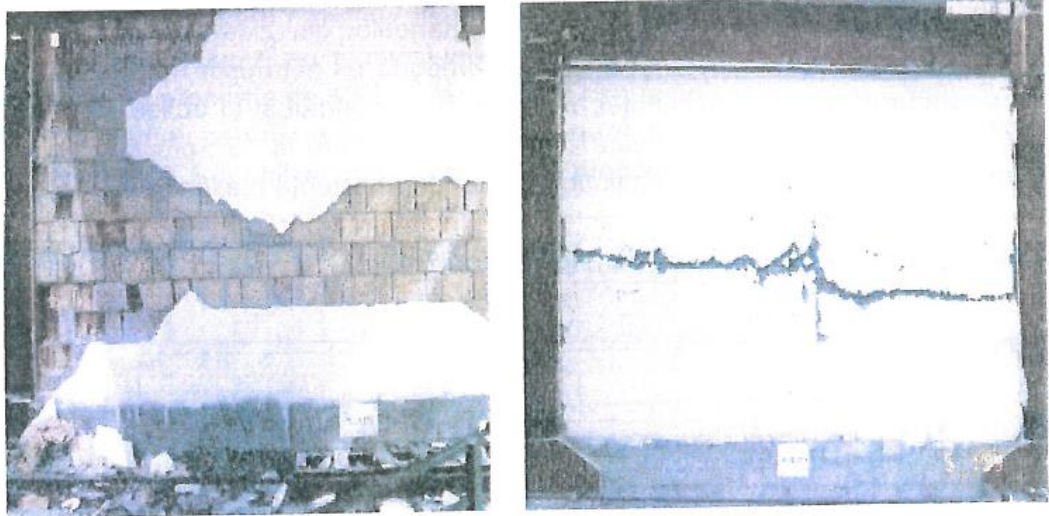


Fig. 2.2.2. The simple masonry panel on the left, and the reinforced masonry panel on the right, at the end of the testing [4]

The comparative aspect of the two panels is also relevant (Fig. 2.2.2.). The unreinforced wall had numerous bricks that were either expelled or crushed. The reinforced masonry panel remained intact, but it was filled on both sides with thin, numerous fissures, inclined at 45 degrees. A horizontal fissure appeared in the centre of the panel, being caused by pure shear efforts. The behaviour of the simple masonry wall demonstrates the inefficiency of bricks with vertical gaps in seismic areas. [4]

### 3. 3D model in natural size with gaps

The behaviour of the 3D model with gapping in natural size was highlighted by the hysteresis curves corresponding to this model. Thus, the response of the simple masonry panel is represented by the blue colour, whereas the response of the reinforced masonry panel is represented by the red colour (Fig. 2.3.1). [4]

The hysteresis curves are not symmetrical due to the arrangement of the gaps in the panel. Until the maximum strength is reached, the behaviour of the simple masonry panel is clearly non-linear. The peak is followed by a very quick degradation phase of the strength. The response of the reinforced masonry wall is also influenced by the arrangement of the gaps. Until the maximum strength is reached, the behaviour is strongly non-linear, but the peak value of the strength is much higher than it is in the case of the



unreinforced variant. Also, the degradation of the strength from cycle to cycle occurs progressively and it is limited. [4]

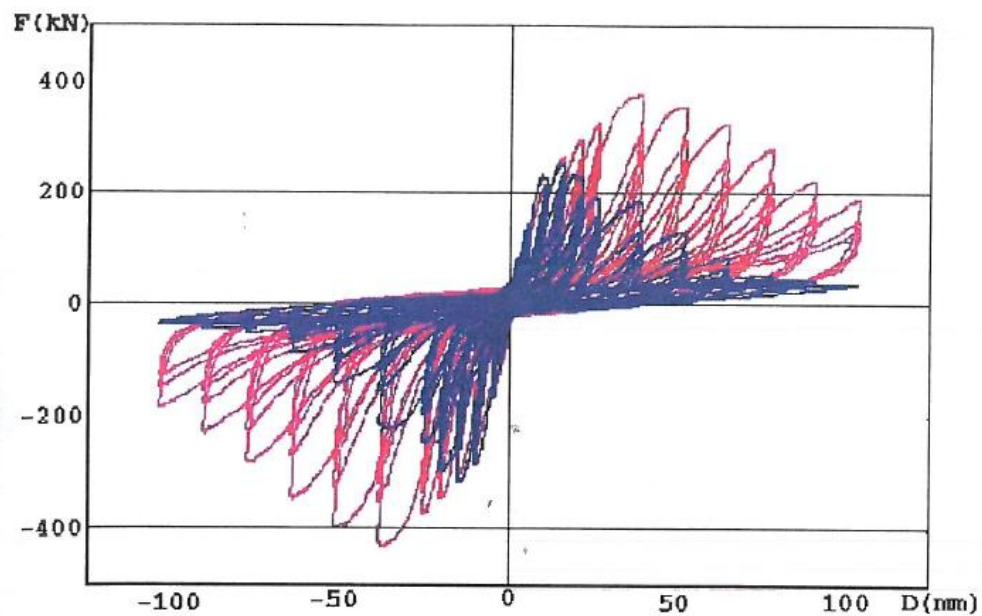


Fig. 2.3.1. The hysteresis curve for the 3D model with gapping [4]

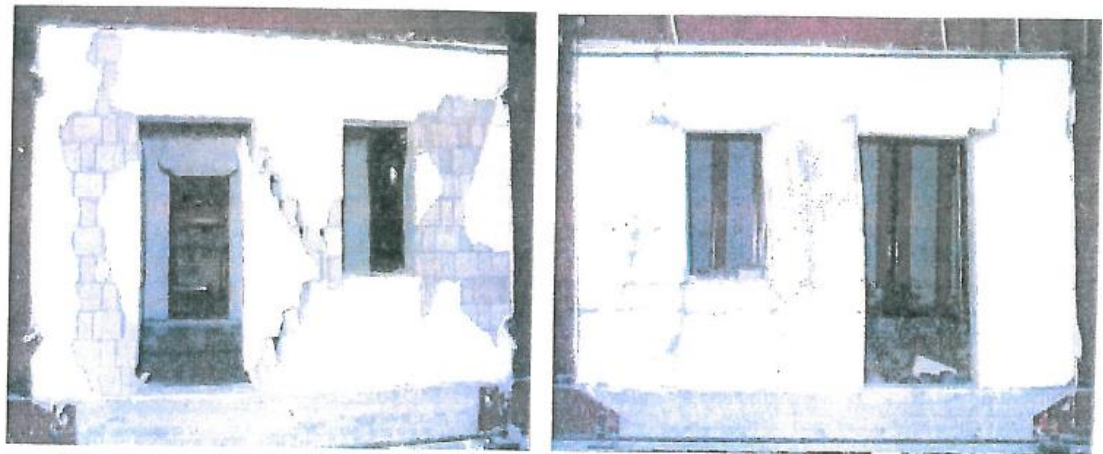


Fig. 2.3.2. The simple masonry panel on the left, and the reinforced masonry panel on the right, at the end of the testing [4]

As it can be noticed in Fig. 2.3.2., the simple masonry panel suffered very serious damage to the central upright, with X-shaped fissures and expelled bricks, as well as fissures at the corners of the gaps. The confined panel retained its integrity. Fissures also appeared in this case at the corners of the gaps, but they were very limited and a central vertical fissure appeared on the middle upright, as a result of pure shearing. [4]

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## **Chapter 3. The Ecoleader Project, ISMES, Bergamo, Italy**

### **1. General data**

The European Ecoleader program took place at the ISMES research centre in Bergamo, Italy, in 2001. It consisted of testing two full-scale 3D models on the MASTER shake table. [4]

Two 3D models of reinforced masonry buildings with life-size RG20 polymeric grids were made. Both of them have a single axis of symmetry. There are no reinforced concrete elements, and the flooring above is made of wooden material. The models were made by hand, with M2 mortar according to EC6, which corresponds to the Romanian lime-cement mortar M10. [4]

In the first phase, the two models were not plastered nor on the inside or on the outside. Instead, reinforcement at the level of the horizontal joints with polymeric grids was used. In the second phase, the same models were repaired and coated with polymeric grids, then plastered with the same M10 mortar. [4]

The tests to which the two models were subjected were based on the 1977 Vrancea earthquake, which had as a basis two degrees of freedom corresponding to the horizontal translations. This earthquake was a model for the induced acceleration diagram. [4]

### **2. 3D model of a patrimonial building made of solid brick masonry with lime mortar in the unconfined variant**

The 3D model of the heritage building was made out of solid brick masonry and lime mortar. The top view dimensions of the model were of 2.78x2.17 m, and the height was of 2.9 m. The thickness of the walls was of 23 cm, and the dimensions of the bricks were of 230x105x60 mm. On two opposite walls, two gaps for windows were made for each wall in a semicircular arch style specific to Brâncuși, having a small pillar between them. A gap for a door was also made with a lintel, in the same semicircular arch fashion. The weight of the model was of 7.2t, while the metallic frame also had 2 t. [4]

The test was stopped when the last state limit was reached, characterised by the collapse of the model. Some parts of the model were torn off, leading to the polymeric grid breaking down. The highlighted fissures corresponded to the corners of the openings and the small pillars between the windows, these also being areas of dislocation. [4]



Fig. 3.2.1. The 3D model for the solid brick masonry [4]

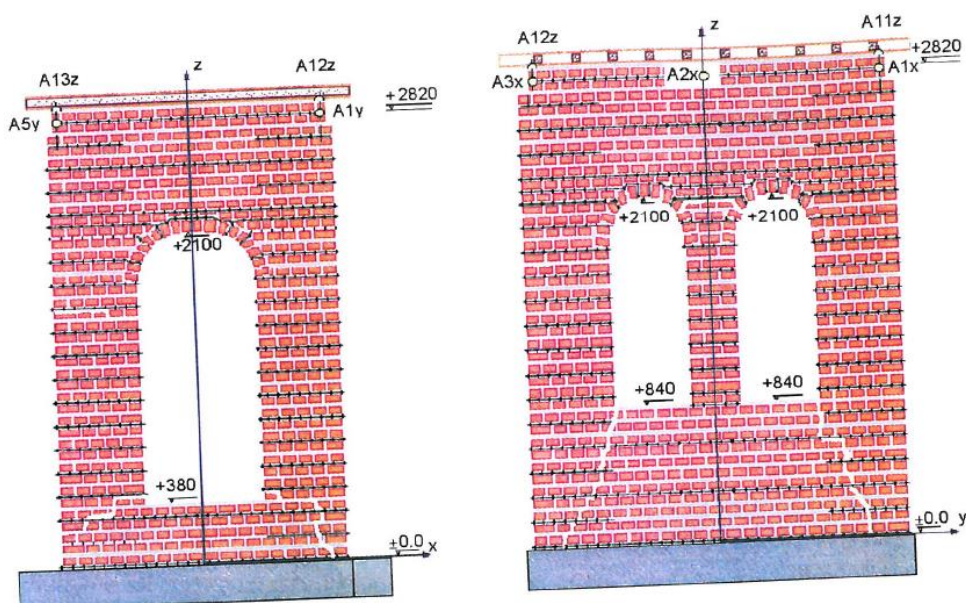


Fig. 3.2.2. The western wall (left) and the southern wall (right) of the solid brick model, after testing, highlighting the fissures [4]



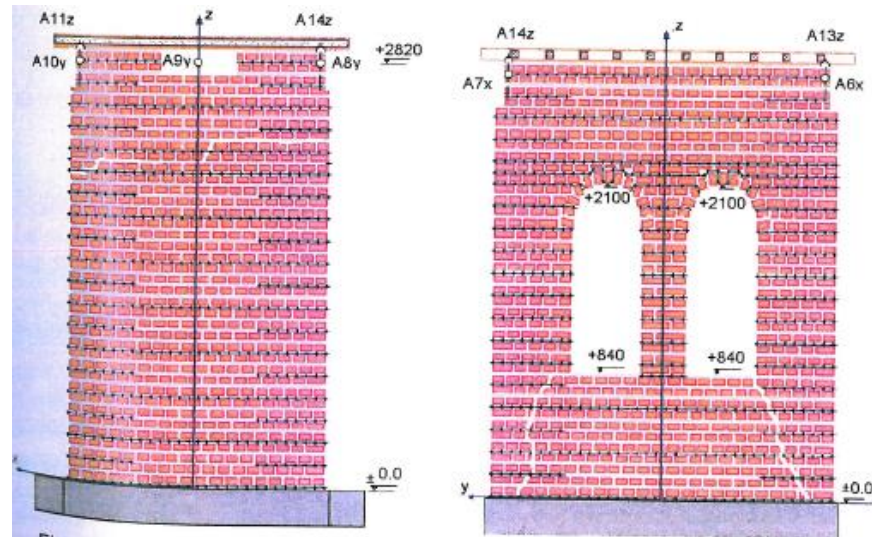


Fig. 3.2.3. The eastern wall (left) and the northern wall (right) of the solid brick model, after testing, highlighting the fissures [4]

### 3. 3D model of a patrimonial building made of solid brick masonry with lime mortar in the confined with polymeric grids variant

The heritage building model, a building which was made of solid brick masonry and lime mortar was, after testing, repaired and strengthened by jacketing with polymeric grids and plastering with the very same mortar.

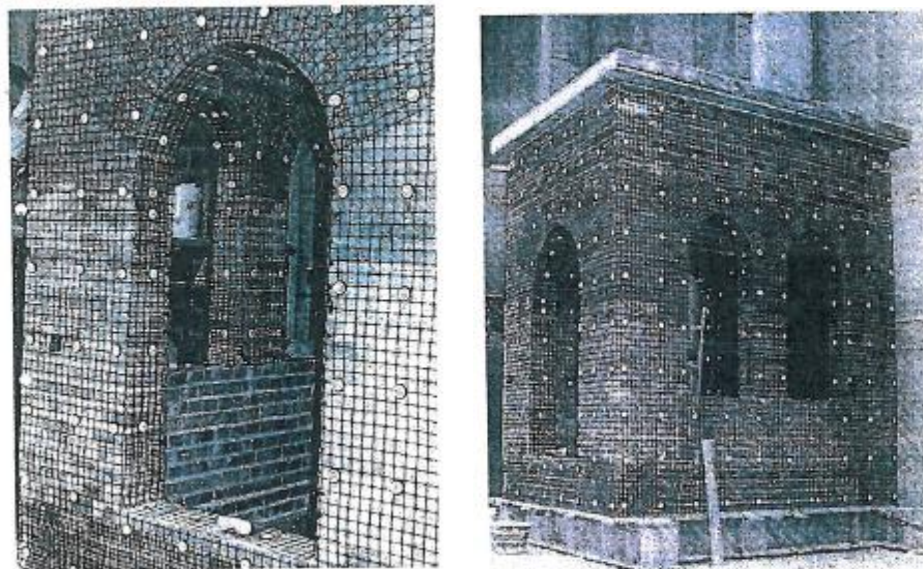


Fig. 3.3.1. The consolidation of the solid masonry with lime mortar model by jacketing with polymeric grids [4]

The consolidated model was also subjected to excitations based on the 1977 Vrancea registration, which involved two degrees of freedom. The intensity of the movements was higher, the test stopping when the final state limit was reached. Unlike the first test, on the unconfined model, the final state limit in this case was represented by stability on the seismic mass. The model began to jump off the seismic mass, however it was able to retain its structural integrity.



Fig. 3.3.2. The solid masonry with lime mortar model – consolidated [4]

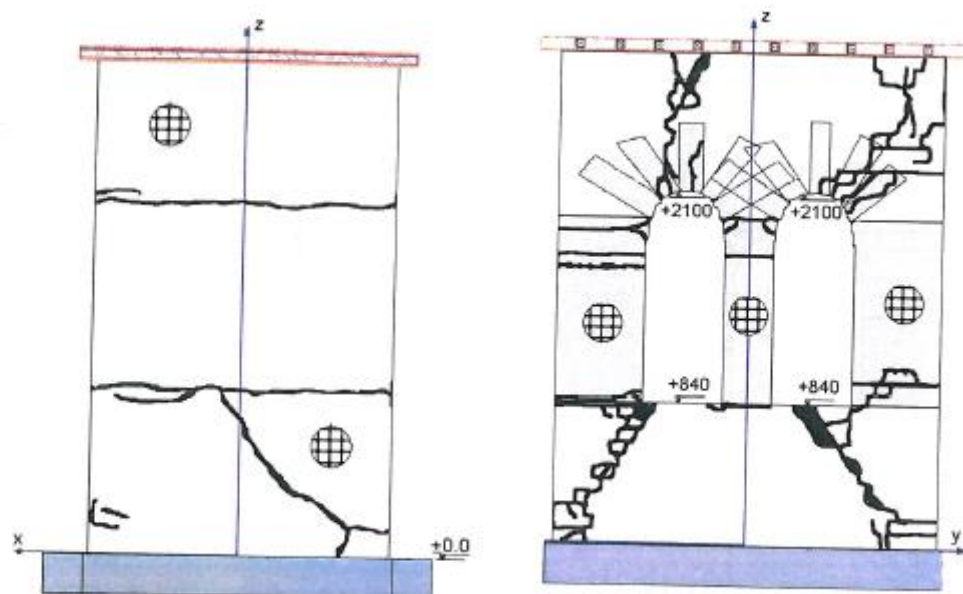


Fig. 3.3.3. The eastern wall (left) and the northern wall (right) of the confined model made of solid bricks, after testing, highlighting the cracks [4]

From the point of view of degradation, cracks developed at 45 degrees at the corners of the gaps, while local effects caused by bearing could also be noticed. However, the model has retained its integrity. After uncovering the plaster, it was found that the reinforcement had given way, but the bricks remained intact (Fig. 3.3.4.). This mechanism has positive effects, proving that in the case of solid brick masonry, coating with polymeric grids is a reversible process. Also, the repair of such masonry is a simple process, since the bricks retain their integrity and the replacement of polymeric grids is relatively easy to perform. [4]

The added flexibility of the brick masonry and lime mortar allowed for certain deformations of the bricks and mortar to take place. They led to a protection of the integrity of the element. Philosophically, it can be mentioned that this degree of seismic protection is due to the *Æsop* effect, known from the fable "The Oak and the Reed".

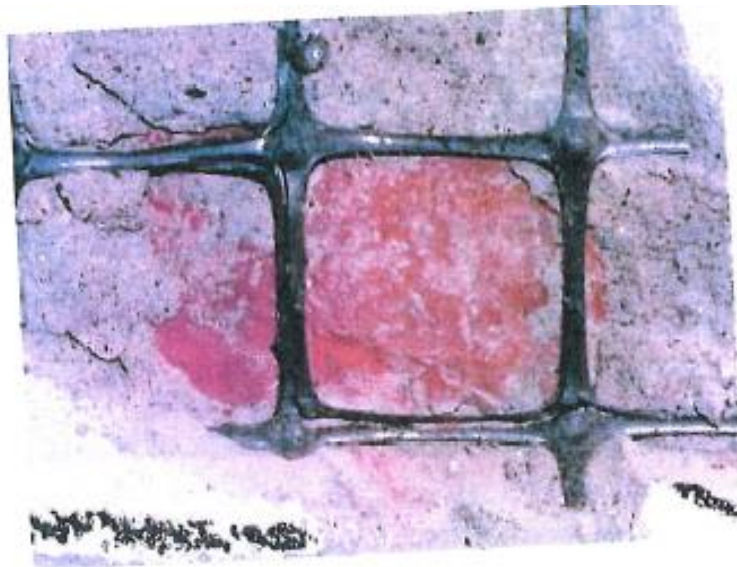


Fig. 3.3.4. The model made of solid bricks – the bricks remained intact, but the reinforcement broke down [4]

#### **4. 3D model of a patrimonial building made of hollow brick masonry and lime-cement mortar in the unconfined variant**

The full-scale 3D model was made out of hollow bricks and lime-cement mortar. The top view dimensions of the model were of 2.75 x 2.45 m, and the height was of 3.23 m. The thickness of the walls was of 20 cm. Three rectangular gaps were made for the doors and windows, and the solid wall was curved out of its plane. The flooring was made out of reinforced concrete without a belt. The model had the same weight of 7 t, placed on the same metallic frame weighing 2 t. The dimensions of the bricks were of 200x140x230 mm. A polymeric grid reinforcement was placed at the level of each joint. [4]



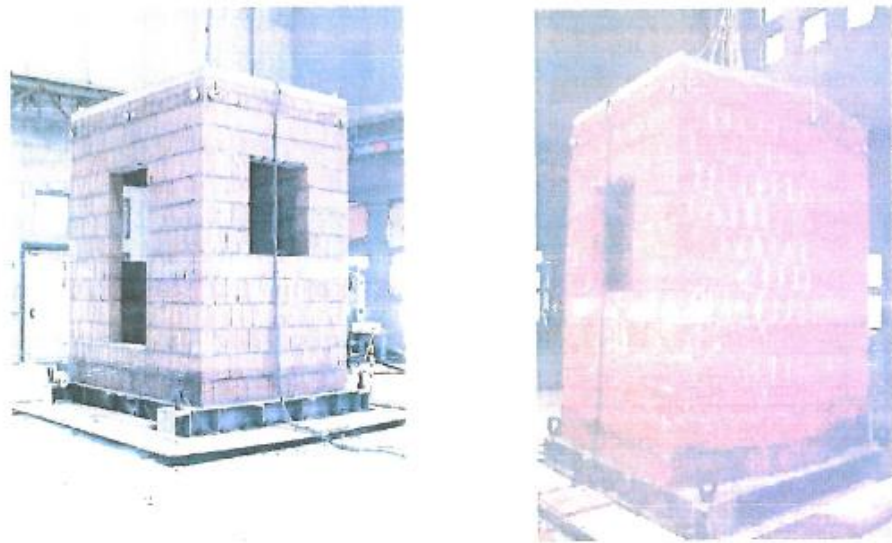


Fig. 3.4.1. The model made out of hollow bricks [4]

The model was also subjected to a test based on the registration of Vrancea 1977. After stopping the test, cracks that appeared both inside and outside the model could be inspected. The cracks were either vertical or slightly inclined in relation to the vertical line, but never shaped as an X. Although major fissures appeared, the polymeric grid located in the horizontal mortar layer between the bricks resisted, not ending up broken, but only punctually deformed.

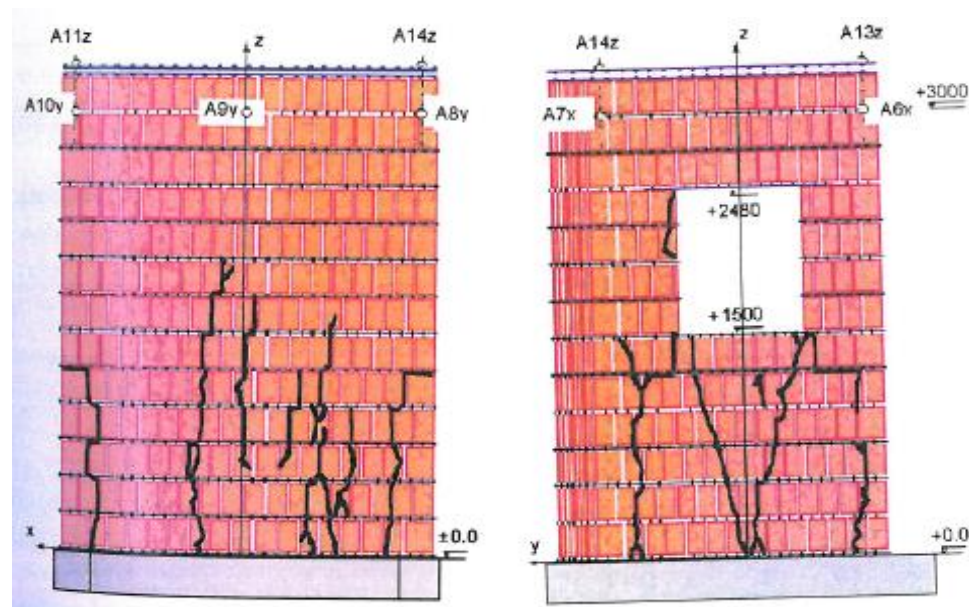


Fig. 3.4.2. The masonry model made of hollow bricks with highlighted cracks for the eastern wall (left) and the northern wall (right) [4]

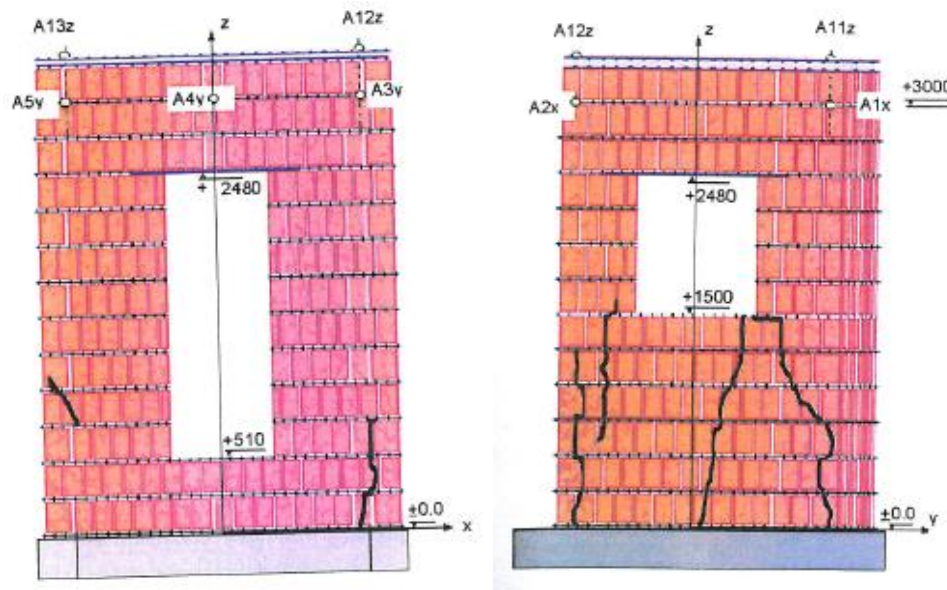


Fig. 3.4.3. The masonry model made of hollow bricks, with cracks being highlighted for the western wall (left) and the southern wall (right) [4]

It was found that the cracks are continuous and they either go through the vertical joints, or split whole bricks. The damages are not concentrated or localised, therefore showing that the grids have been active. [4]

#### 5. 3D model of a patrimonial building made of hollow brick masonry with lime-cement mortar in the confined with polymeric grids variant

The model made of hollow brick masonry with lime-cement mortar was subsequently repaired and consolidated. The model was lined with polymeric grids and then plastered with lime-cement mortar. [4]

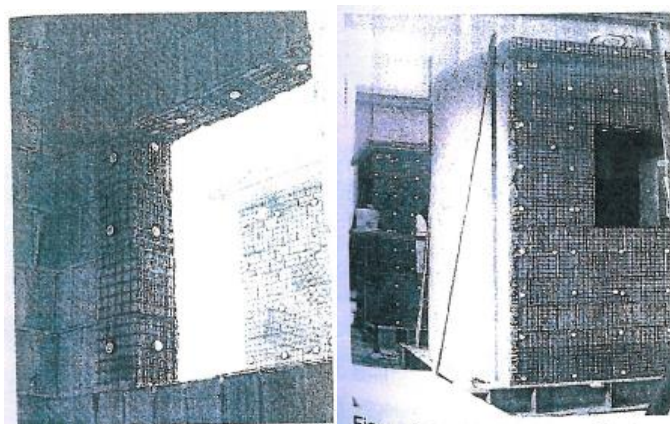


Fig. 3.5.1. The consolidation of the hollow masonry and lime-cement mortar model by jacketing with polymeric grids [4]



The consolidated model was also subjected to excitations based on the 1977 Vrancea registration, considering two degrees of freedom. The intensity of the movements was higher, the test stopping when the final limit state was reached. The model was severely damaged, but it did not collapse, so it is believed that it could be repaired. The curved wall resisted and was not subjected to the phenomenon of deplanation, and the explanation lies in the reinforcement with polymeric grids. The lack of fissures at the angle of 45 degrees shows that the confined and coated masonry withstands the shear forces quite well. The vertical or slightly inclined fissures appeared due to the local bearing efforts on the metallic frame. Most of the fissures are horizontal and appeared through displacement along the joints between the ceramic hollow bricks, as a consequence of their rigidity. [4]

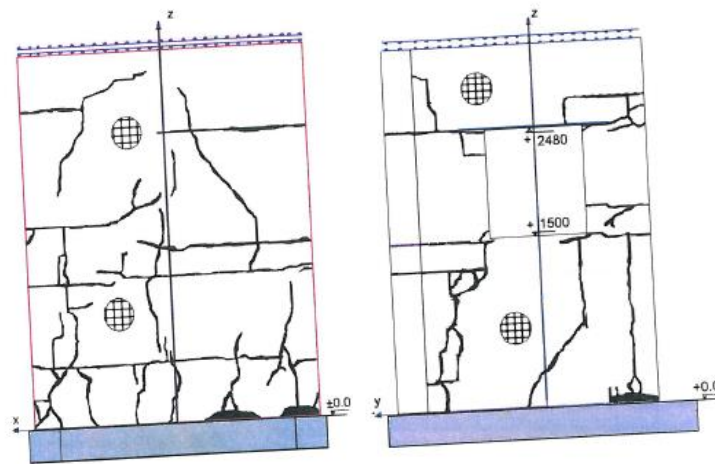


Fig. 3.5.2. The hollow brick masonry model that is confined, with fissures highlighted for the eastern wall (left) and the northern wall (right) [4]

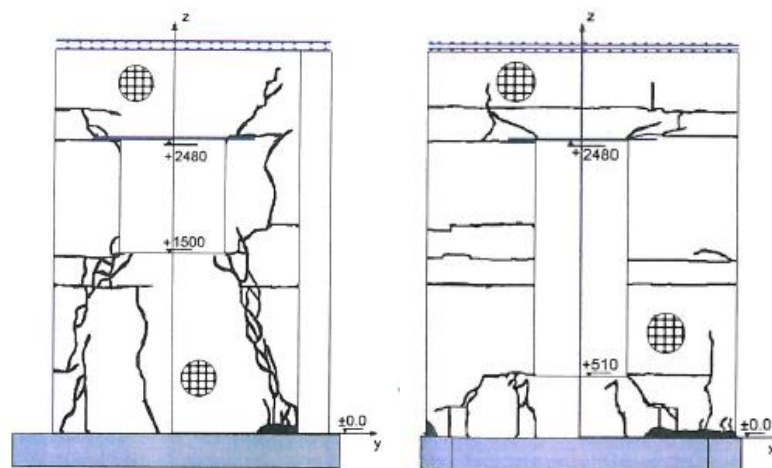


Fig. 3.5.3. The hollow brick masonry model that is confined, with fissures highlighted for the western wall (left) and the southern wall (right) [4]

After finishing the test, the plaster was uncovered in order to properly notice the consequences. It was found that the reinforcement made of polymeric grids was still intact, while the bricks broke down (Fig. 3.5.4.). This type of response from the model is unfavourable and of a lower quality when compared to the solid brick model. The main disadvantage is the fact that the hollow masonry that is confined is proven to be very difficult to repair or consolidate. Also, it is proven that this type of masonry is inefficient in seismic areas.

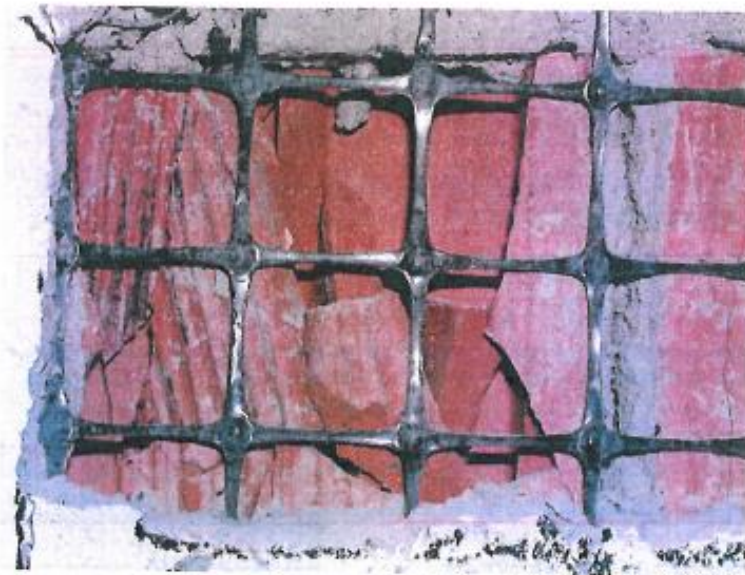


Fig. 3.5.4. The hollow brick model – the reinforcement is still intact, while the bricks broke down [4]

## **Chapter 4. The ASTRA polygon, Ploiești**

### **1. General data**

In 2003, a test was performed at the ASTRA test site in Ploiești. The purpose of the experiment was to evaluate the behaviour of an existing construction which was reinforced with polymeric grids, with integrated rigid knots in the case of impact situations. [23]

The following cases were considered:

- Underground explosions near the building;
- Aerial explosions at a certain distance from the wall;
- Explosions inside the building;
- Powerful explosions from a distance. [23]

For this purpose, a building with load-bearing masonry was made. It was also confined with polymeric grids. (Fig. 4.1.1.)

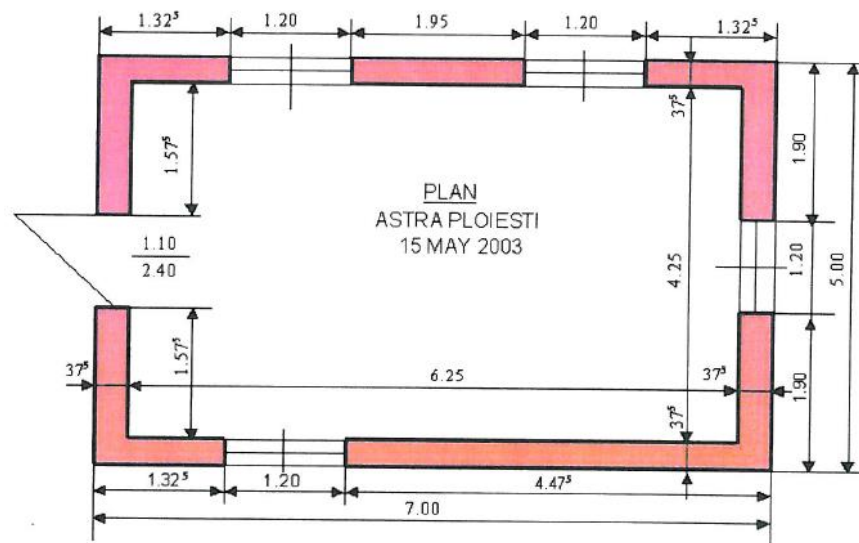


Fig. 4.1.1. Top view of the building subjected to the experiment [23]

The goals were to locate the shock, to dissipate the induced energy and to locally concentrate the unitary efforts.

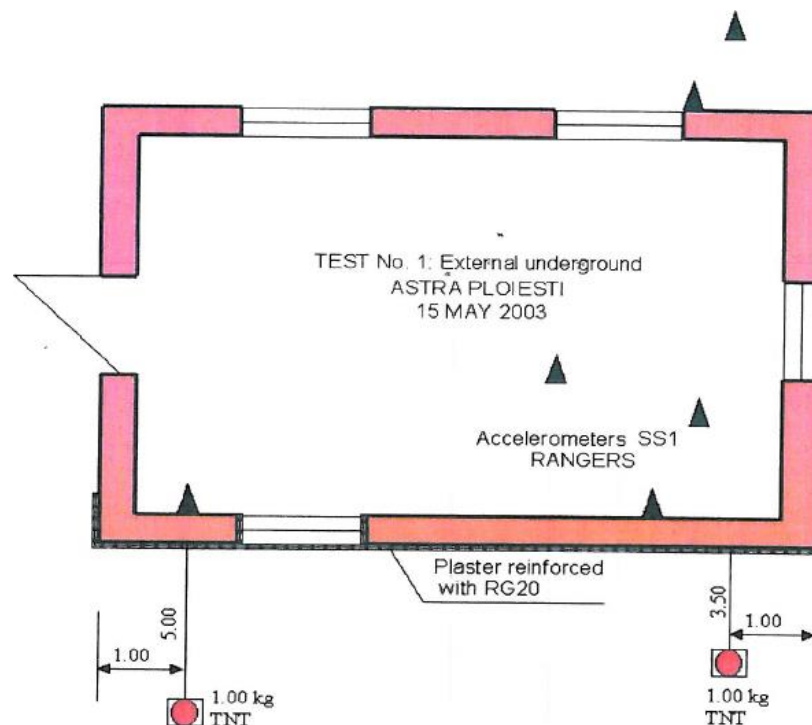


Fig. 4.1.2. Positions of the external explosives and the accelerometres [23]

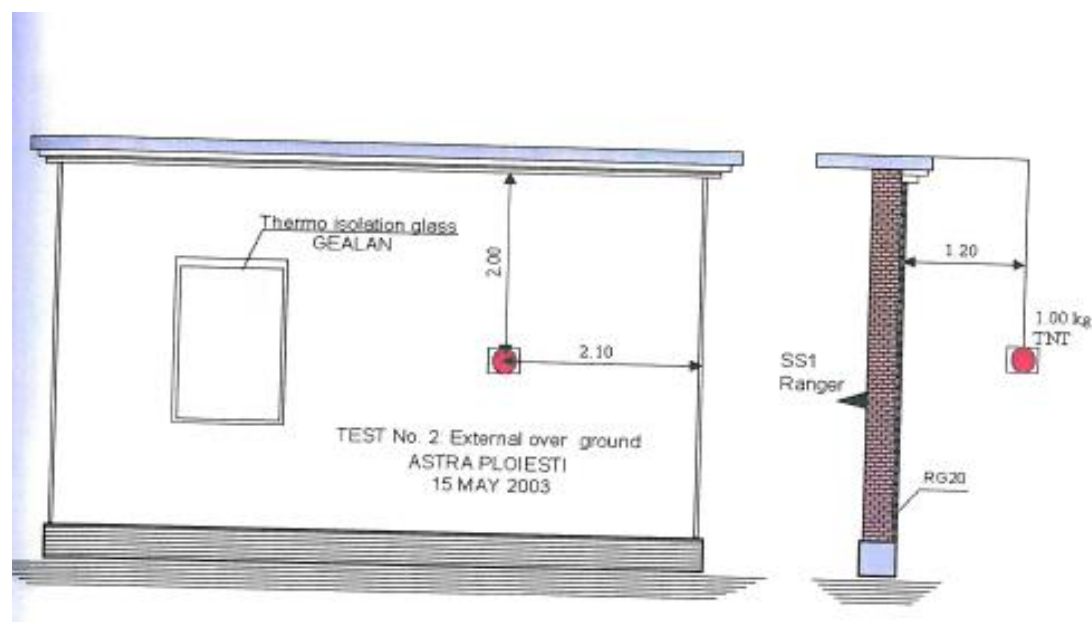


Fig. 4.1.3. Positions of the explosives when checking the perpendicular effect on the plane of the wall [23]

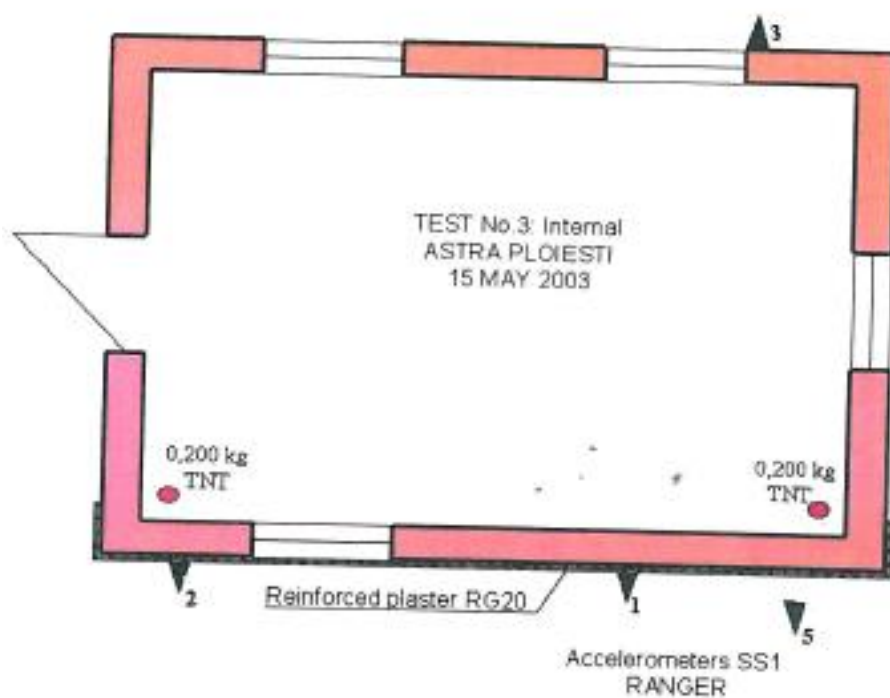


Fig. 4.1.4. Positions of the explosives inside the structure [23]

## 2. The results of the experiment

The building which was subjected to the experiment had a favourable response in the case of the explosions. Therefore, the structure did not lose its structural integrity or stability. Only local degradations could be noticed. However, they did not pose a threat to the structure as a whole. [23]

The polymeric grids were proven to be efficient in protecting the building from explosive shocks. They took over the energy from the explosions, which could be identified as a local concentration of unitary efforts, and contributed to its dissipation. [23]

## Chapter 5. INCERC, Iași, Romania

### 1. General data

An experiment was performed in the INCERC Iași test laboratory. Three panels made of solid masonry, with top view dimensions of 1.115 m x 2.70 m were subjected to an impact with a conical weight of 50 daN. The static scheme is made of a simply supported beam, and the force at which the walls are stressed is applied in the middle of them, leading to a response to shocks by bending. [23]

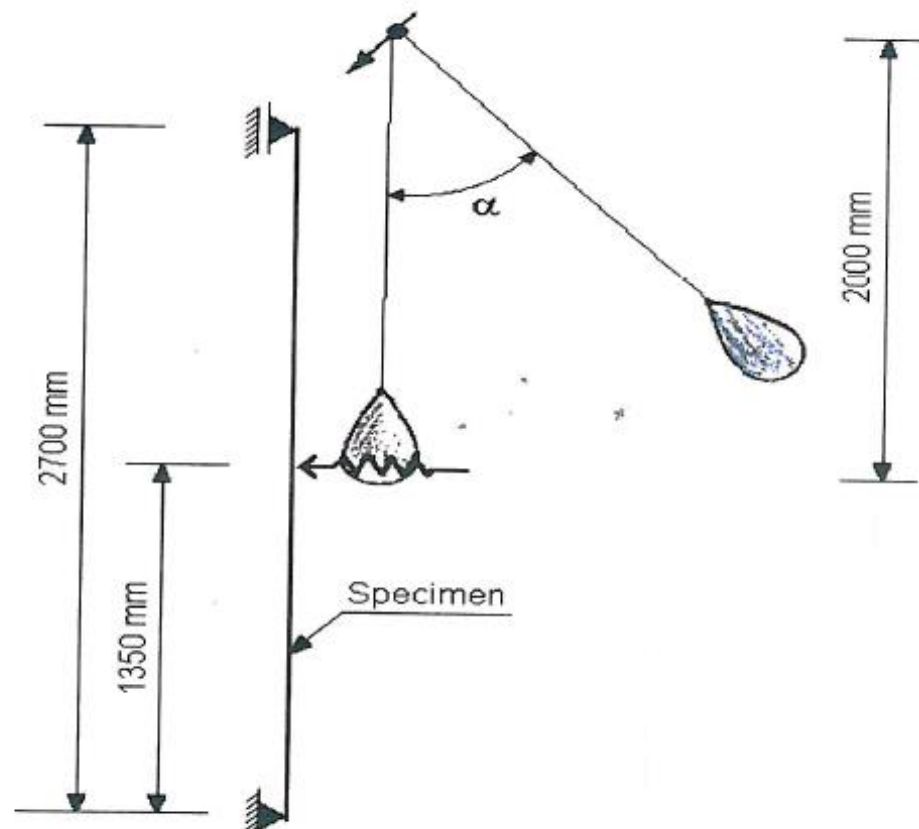


Fig. 5.1.1. Loading of the panels scheme used for the test at INCERC, Iași [23]



The three panels were made of simple masonry, with solid pressed bricks and lime-cement mortar. The first panel was tested in this state. The second one was confined with RG40 polymeric grids, while the third one was confined with welded mesh. [23]

## 2. The results of the experiment

According to SR ISO 7892/98, the weight was launched successively from greater heights, with a tilting of the pendulum of 10°, 15°, 22°, 30°, 35°, 44°, 55°, 60°, 66°. [23]

The first panel, made of plain masonry, cracked after the first hits, therefore having an unfavourable response, characterised by plastic deformations. Therefore, there were great values of the displacements, while fissures could also be observed.

The two confined panels had a favourable response, almost completely within the elastic domain. The one reinforced with polymeric grids had a ductile behaviour, showing warning cracks. The one confined with welded mesh stayed within the elastic domain, however it could be predicted that its collapse was about to occur by suddenly crushing the breakable bricks without any warning whatsoever. [23]

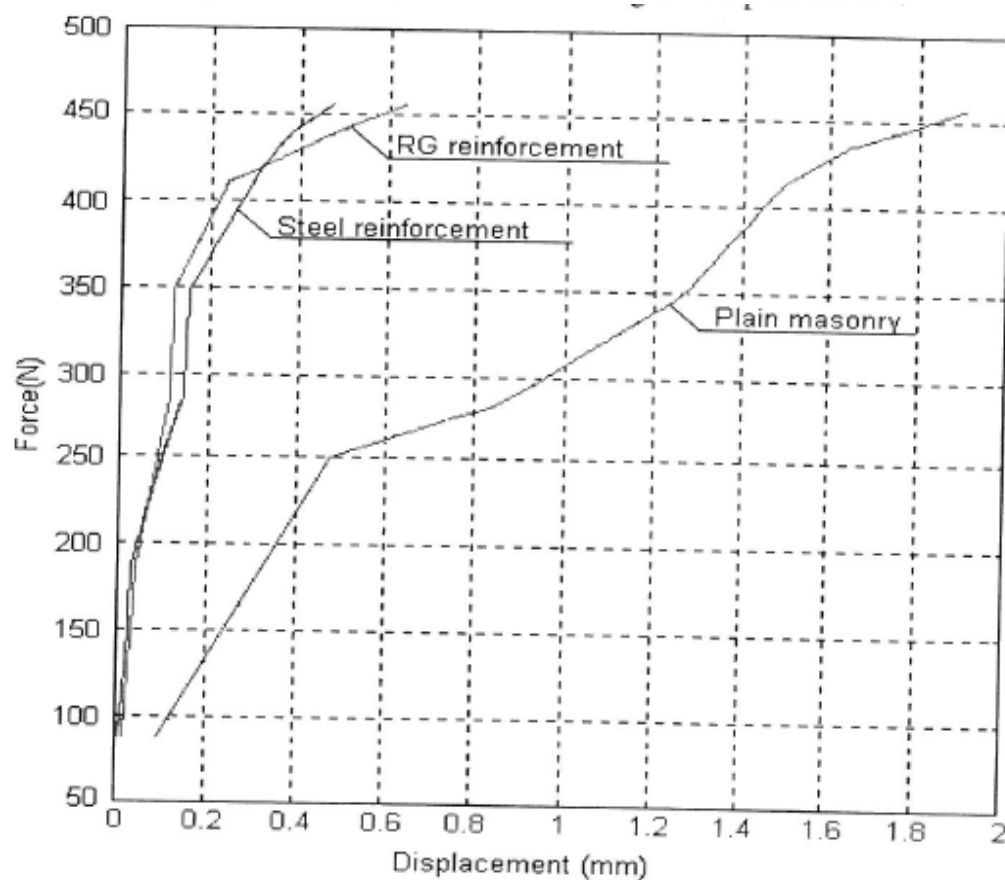


Fig. 5.2.1. The force-displacement diagram for the three panels [23]

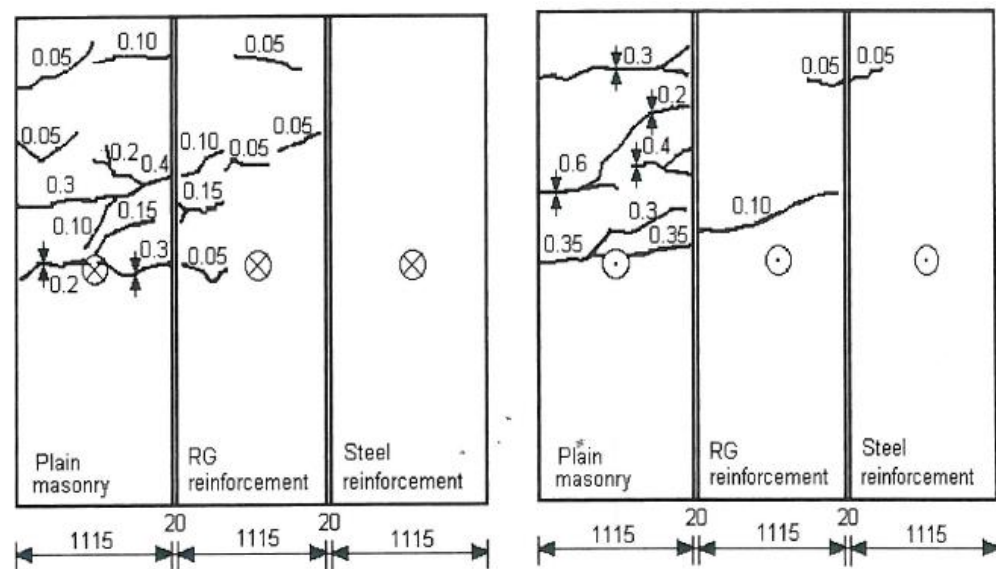


Fig. 5.2.2. Reviews of the cracks on the two sides of the three panels [23]

## Chapter 6. ISMES, Bergamo, Italy

### 1. General data

Within the ISMES laboratory, from Bergamo, Italy, an experiment was performed in order to determine the ability of a model coated with polymeric grids to absorb shock-induced stresses. A full-scale model was used, made of bricks with vertical gaps and lime-cement mortar, coated with polymeric grids. The model had been previously subjected to three series of tests on the shaking table, leading to areas with fissures appearing. [23]

Two contact points were chosen, one in a cracked area and the other one in an uncracked area. The shocks were induced by a steel cylinder, launched successively at the level of the two points from increasing heights, of 0.1 m, 0.2 m, 0.3 m, 0.4 m, 0.5 m.

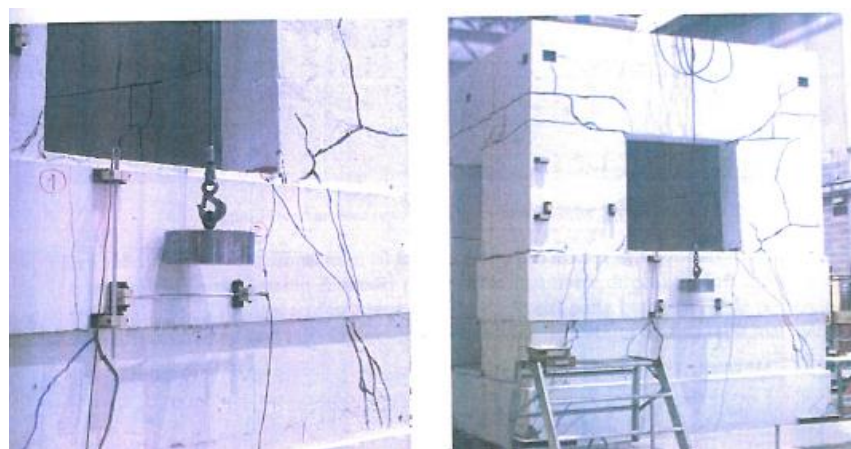


Fig. 6.1.1. First contact point on the reinforced plaster belt [23]



Fig. 6.1.2. The second contact point on the coating of the wall in an area without cracks [23]

## 2. The results of the experiment

The effects of the impact during the application of the shocks were recorded electronically. Thus, no cracks or microcracks could be found in the experimental model. The only degradations which could be found were at the contact points of the pendulum with the surfaces of the wall. [23]

At the first point, the mortar was detached after each impact to depths between 0.8 – 1.8 mm. For the second one, the mortar was detached to depths between 4.1 – 5.9 mm.



Fig. 6.2.1. The footprint of the 5 shocks within the first contact point [23]



Fig. 6.2.2. The footprint of the 5 shocks within the second contact point [23]

As in the previous cases, the reinforcement with polymeric grids has proven its efficiency. The shock-induced energy was dissipated by the polymeric grids, avoiding something very harmful to the masonry: concentrations of the efforts. The direct contact between the polymeric grids and the masonry allowed both the easy transfer of energy from the masonry to the grids and its dissipation by rubbing the grids with the masonry.

## Chapter 7. Comparative table

### 1. Presentation of the table

Comparative table showing the physical-mechanical characteristics of the original masonry, based on lime mortar, and the modern masonry, based on cement mortar. [4]

| PHYSICAL-MECHANICAL CHARACTERISTICS                                        | ORIGINAL MASONRY                                 | MODERN MASONRY                             |
|----------------------------------------------------------------------------|--------------------------------------------------|--------------------------------------------|
| 1. Type of mortar                                                          | Lime                                             | Cement                                     |
| 2. Specific weight of the masonry                                          | 18 kN/m <sup>3</sup>                             | 20 kN/m <sup>3</sup>                       |
| 3. Linear thermal expansion coefficient                                    | 4x10 <sup>-6</sup> C <sup>-1</sup>               | 10x10 <sup>-6</sup> C <sup>-1</sup>        |
| 4. Golden rule regarding the mortar/brick strength ratio                   | Yes                                              | No                                         |
| 5. Gravity dependence                                                      | Yes                                              | No                                         |
| 6. Orientation of the mechanical properties                                | Orthotropic                                      | Quasi-isotropic                            |
| 7. Receptivity to seismic actions                                          | No                                               | Yes                                        |
| 8. Embedded energy content                                                 | 5.2 GJ/m <sup>3</sup>                            | 7.4 GJ/m <sup>3</sup>                      |
| 9. Water content                                                           | Dry                                              | Wet                                        |
| 10. Mechanical behaviour                                                   | Ductile                                          | Mechanical                                 |
| 11. Concrete compatibility                                                 | No                                               | Yes                                        |
| 12. Compatible type of reinforcement                                       | Non-metallic, ex. polymeric                      | Metallic, of steel                         |
| 13. Type of reinforcement                                                  | Only passive                                     | Passive and active                         |
| 14. The transfer mechanism of efforts from the mortar to the reinforcement | Through anchoring, with $\sigma$ (sigma) efforts | The vice effect, with $\tau$ (tau) efforts |
| 15. Suitability for pretensioning                                          | No                                               | Yes                                        |
| 16. Suitability for reinforcement with fibres of glass, carbon or metals   | No                                               | Yes, to a limited extent                   |
| 17. Suitability for perforation                                            | No                                               | Yes                                        |

|                                                              |     |    |
|--------------------------------------------------------------|-----|----|
| <b>18. Sandwich effect</b>                                   | Yes | No |
| <b>19. Vault effect</b>                                      | Yes | No |
| <b>20. Reversibility – replacement of the damaged bricks</b> | Yes | No |

Table 7.1.1. Comparative table [4]

## 2. Brief commentary

The table contains a summary of the differences in characteristics between the original masonry, based on solid bricks and lime mortar, and the modern one, based on bricks with vertical gaps and cement mortar.

- (1) The lime mortar can also be considered lime-cement mortar, but with lime in a larger proportion. Cement mortar can also be considered as lime-cement mortar, but with cement as the predominant component. [4]
- (2) The volumetric weight of the original masonry is of  $18\text{kN/m}^3$ , and that of the modern masonry may vary, depending on how much mortar penetrates the vertical gaps. At the limit, in the situation in which the gaps represent 50% of the volume of the bricks and the mortar fills them completely, the volumetric weight can reach the value of  $20\text{kN/m}^3$ .
- (3) These values of the thermal expansion coefficient are mentioned within Eurocode 6. It is noted that modern masonry has a thermal expansion coefficient similar to that of concrete, but very different from that of historical masonry. This is one of the reasons why historical masonry is not compatible with the traditional reinforced concrete jacketing solution.
- (4) The so-called “Golden rule” states that the strength of the mortar must be inferior to the strength of the bricks. [4]
- (5) The original masonry is gravity dependent since the execution phase, as the most appropriate placement of the bricks depends on gravity; it is done before the mortar hardens and the horizontality of the joints is essential. In the case of modern masonry, the bricks are placed after the hardening of the mortar, which has more strength than the bricks, therefore the contact does not depend on gravity. [4]
- (6) The distinctive mechanical properties are owed to the strength of the mortar, which in the case of modern masonry has more strength, leading to its quasi-isotropic behaviour.
- (7) The original masonry was conceived exclusively for gravitational actions.



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- (8) The higher energy content of the modern masonry is due to the burning up of both the clay within the hollow bricks to the point of vitrification, and the cement. [4]
  - (9) Cement mortar has water within its structure, while lime mortar does not. [4]
  - (10) Under gravitational actions, lime mortar has predominantly plastic deformations, while cement mortar has quasi-elastic deformations. Subjected to seismic actions, both types of mortar have an elastic behaviour. [4]
  - (11) Modern masonry is compatible with concrete because the modulus of elasticity has similar values for both materials. This cannot be said of original masonry and concrete. The different values for the modulus of elasticity prevents these materials from cooperating, making them incompatible. [4]
  - (12) The lime mortar within the historical masonry corrodes the metallic reinforcement. [4]
  - (13) Classical masonry cannot be actively reinforced, thus pretensioned, because of its small and permanent deformations. [4]
  - (14) The polymeric reinforcement cooperates with the lime mortar through anchoring, so that normal efforts are involved, while the steel reinforcement cooperates with the cement mortar through the vice effect, so that tangential efforts are involved. [4]
  - (15) Modern masonry can be pretensioned according to Eurocode 6. [4]
  - (16) Experiments have shown that original masonry is not suitable for carbon or glass fiber reinforcement. [4]
  - (17) The perforation of the original masonry leads to the appearance of stress concentrators, according to Landau's Theory of Dislocations.
  - (18) The sandwich effect consists in the spontaneous plastic deformation of the lime mortar, which leads to the phenomenon of adaption, involving an avoidance of the local concentrations of efforts, therefore preventing dislocations. [4]
  - (19) The vault effect consists in unloading vertical, gravitational actions within inclined directions, leading to a decrease of their intensity. [4]
  - (20) In the case of original masonry, the damaged bricks or the degraded reinforcement may be replaced. [4]

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## Chapter 8. CONCLUSION

The presented experiments revealed certain characteristics of the different types of load-bearing masonry. These were analysed comparatively, in relation to their behaviour when confined with polymeric grids.

Solid brick masonry with lime mortar has weak characteristic strengths. However, experiments have shown the efficiency of this type of masonry, due to its flexibility. From a philosophical standpoint, this degree of seismic protection is due to the *Æsop* effect, known from the fable "The Oak and the Reed". Confinement with polymeric grids has been proven to be adequate, because the masonry maintains its integrity, while the grid reinforcement is plasticized.

Hollow brick masonry with cement mortar has higher characteristic strengths. However, it has been proven to be inefficient in seismic areas, because of its higher rigidity and lack of ductility. The *Æsop* effect also explains this behaviour. Coating with polymeric grids would rather lead to crushing the bricks and maintaining the integrity of the grids.

Confinement with polymeric grids has been proven to be the right solution to correct the inefficiency of masonry at concentrated efforts. It manages to compensate for the potential dislocations generated by the  $\sigma$  efforts at the level of the geometric imperfections, specific to the masonry, according to Laundau's Theory. [24]

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## LISTING OF FIGURES

Fig. 1.1. The  $\sigma$  efforts subjected to a force, highlighting the geometric imperfections, on the left and the attenuation of the efforts with the help of the grids, on the right [4]

Fig. 2.1.1. The two 3D models, one with gaping and the other one without gaping [4]

Fig. 2.2.1. The hysteresis curve for the 3D model without gaping [4]

Fig. 2.2.2. The simple masonry panel on the left, and the reinforced masonry panel on the right, at the end of the testing [4]

Fig. 2.3.1. The hysteresis curve for the 3D model with gaping [4]

Fig. 2.3.2. The simple masonry panel on the left, and the reinforced masonry panel on the right, at the end of the testing [4]

Fig. 3.2.1. The 3D model for the solid brick masonry [4]

Fig. 3.2.2. The western wall (left) and the southern wall (right) of the solid brick model, after testing, highlighting the fissures [4]

Fig. 3.2.3. The eastern wall (left) and the northern wall (right) of the solid brick model, after testing, highlighting the fissures [4]

Fig. 3.3.1. The consolidation of the solid masonry with lime mortar model by jacketing with polymeric grids [4]

Fig. 3.3.2. The solid masonry with lime mortar model – consolidated [4]

Fig. 3.3.3. The eastern wall (left) and the northern wall (right) of the confined model made of solid bricks, after testing, highlighting the cracks [4]

Fig. 3.3.4. The model made of solid bricks – the bricks remained intact, but the reinforcement broke down [4]

Fig. 3.4.1. The model made out of hollow bricks [4]

Fig. 3.4.2. The masonry model made of hollow bricks with highlighted cracks for the eastern wall (left) and the northern wall (right) [4]

Fig. 3.4.3. The masonry model made of hollow bricks, with cracks being highlighted for the western wall (left) and the southern wall (right) [4]

Fig. 3.5.1. The consolidation of the hollow masonry and lime-cement mortar model by jacketing with polymeric grids [4]

Fig. 3.5.2. The hollow brick masonry model that is confined, with fissures highlighted for the eastern wall (left) and the northern wall (right) [4]

Fig. 3.5.3. The hollow brick masonry model that is confined, with fissures highlighted for the western wall (left) and the southern wall (right) [4]

Fig. 3.5.4. The hollow brick model – the reinforcement is still intact, while the bricks broke down [4]

Fig. 4.1.1. Top view of the building subjected to the experiment [23]

Fig. 4.1.2. Positions of the external explosives and the accelerometres [23]

Fig. 4.1.3. Positions of the explosives when checking the perpendicular effect on the plane of the wall [23]

Fig. 4.1.4. Positions of the explosives inside the structure [23]

Fig. 5.1.1. Loading of the panels scheme used for the test at INCERC, Iași [23]

Fig. 5.2.1. The force-displacement diagram for the three panels [23]

Fig. 5.2.2. Reviews of the cracks on the two sides of the three panels [23]

Fig. 6.1.1. First contact point on the reinforced plaster belt [23]

Fig. 6.1.2. The second contact point on the coating of the wall in an area without cracks [23]

Fig. 6.2.1. The footprint of the 5 shocks within the first contact point [23]

Fig. 6.2.2. The footprint of the 5 shocks within the second contact point [23]

## **LISTING OF TABLES**

Table 7.1.1. Comparative table [4]