

Article

An Innovative, Lightweight, and Sustainable Solution for the Integrated Seismic Energy Retrofit of Existing Masonry Structures

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Abstract: A large percentage of existing building stock in Italy and throughout Europe is ageing and no longer complies with current regulations, particularly in terms of sustainability. For these reasons, an urgent consolidation plan is needed to ensure an increase in both seismic response and energy response. Indeed, these constructions were built before the actual technical codes, and currently, they are not able to withstand seismic actions. Meanwhile, they are subject to thermal dispersions that could be due to the use of materials with poor properties or construction errors. Among the numerous consolidation techniques, an innovative solution consisting of a coating system has appeared on the construction market in recent decades. It is an integrated solution that simultaneously improves the seismic and energy behaviour of the building. The paper proposes the evaluation of this lightweight and sustainable solution through some experimental tests which were performed at the National Institute for Research and Development in Constructions, located in the city of Timișoara (Romania). The tests were aimed to investigate the out-of-plane behaviour of a masonry wall (1.20 m × 2.40 m × 0.60 m) obtained by combining two smaller panels with mortar and subjecting them to constant vertical force and pushing by an increasing horizontal one. Its response was assessed before and after the application of extruded aluminium alloy base profiles belonging to the system under study.

Keywords: masonry buildings; integrated seismic energy coat; aluminium alloy system; experimental test



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1. Introduction

In Italy and other parts of Europe, a consistent portion of the existing building stock is represented by masonry structures dating back to the first half of the 20th century or earlier. Therefore, most of these constructions are in an advanced state of decay, showing several injuries [1]. First of all, historical masonry buildings are not able to handle seismic actions, since they were built taking into account only gravity loads [2,3]. They could undergo collapse of both partial and global types, or out-of-plane mechanisms such as simple or partial overturning due to the lack of connection between adjacent walls or among vertical panels and horizontal slab. Additionally, there could be cracks due to the age of the material or disintegration of the mortar used for joints, and lesions could appear on masonry arches and vaults due to the increase in the load. In the end, horizontal slabs may also exhibit deflection of the wooden beams which, in turn would not be able to clamp with the vertical walls and would provoke their detachment [4–6].

The seismic vulnerability assessment of existing historical masonry buildings is a very challenging task in the engineering field due to a lack of information, which is connected to the absence of a real design project. Indeed, in ancient times, the constructions were erected

thanks to the knowledge of the workers. Another problem is the limited knowledge of the material used for the building activities [7]. Furthermore, in the majority of cases, the masonry buildings are not isolated, but they are grouped to form aggregates, which are composed of several adjacent structural cells that are not well connected to each other [8].

Nevertheless, in the last few years, many researchers have proposed numerous different approaches to studying the seismic behaviour of existing masonry structures, both in isolated and aggregate configurations, from the urban scale to single edifices [9,10].

Besides structural problems, these ancient constructions are often subjected to energy issues. Indeed, they appear inadequate, having high values of thermal dispersions derived from the presence of thermal bridges and the absence of a proper isolation layer. Another source of dispersion is represented by the incorrect installation of the window frames; the roof structures; or, in the end, the cooling/heating systems. The thermal inefficiency leads to high and unaffordable costs [11].

In general, according to the latest studies on the topic, the construction sector is responsible for a large portion of CO₂ emissions [12] and consumes a significant amount of heating and cooling costs [13–16].

Hopefully, during recent decades, a greater awareness of climate change has developed and the pressing need to intervene on the structure has become more evident. For instance, the EU enacted the European Green Deal (Communication 2019/640) and the associated Renovation Wave strategy [17,18]. Similar initiatives are widespread even in the USA [19]. Also, the Italian government, starting in 2017, introduced an instrument to promote a green revolution with the so-called ECO-BONUS [20,21].

However, this law caused a separation between energy and seismic interventions. The former were commonly widespread since they were more concrete, ensuring a reduction in the cost of bills, and they provoked a reduced number of interventions under the seismic aspect.

In order to improve the seismic performance of buildings, over the last few decades, starting in Japan, several retrofit strategies have been developed and proposed, such as braced-frame substructures. These include two main types ((i.e., concentrically and eccentrically braced frames). These substructures provide greater lateral stiffness and increased load-bearing capacity [22,23].

Taking into account the climatic emergency and the compulsoriness of adapting existing buildings to the net-zero-energy building model, further innovative solutions have been developed in recent years in the construction market. They allow for simultaneous improvement of the performance of existing masonry buildings from a seismic and energy point of view. The presence of seismic-resistant components ensures the safety of the structure and avoids the loss of human life, as has occurred during previous earthquakes (in Italy several times, in Turkey and Siria in 2023, and in Morocco in 2023, just to name a few, in addition to more recent episodes). In addition, the seismic events generate losses in terms of architectural heritage. This new solution proposes an integrated way to consolidate an existing building, and there are two typologies: the first uses reinforced concrete shear walls, while the other one uses metal exoskeletons coupled with insulating panels [24–26].

Various alternatives have been discussed in previous papers in the literature [27], and some of them are briefly mentioned below.

In the first category, there is the Geniale Ecosism© system produced by the ECO-SISM company, which is made up of thin, cast-in-place, reinforced concrete walls that are connected to the perimeter panels and to the foundations [28]. The same company also manufactures the Karma Coat, which is less invasive. It could be used to avoid the overturning phenomenon of the infill walls in RC structures [29].

On the other side, there are more solutions. One of them is the Sisma Coat system, which uses cold-formed steel profiles [30]. Also, Betontherm, by Beton Wood company, uses a composite timber-cement panel constitutes a light-integrated technique [31].

A further light coating system is the Duo System, which is based on a base frame made up of cold-formed aluminium alloy profiles filled with insulating panels and finished with the placement of OSB panels or trapezoidal sheeting [32].

In this framework, the Resisto 5.9 system, developed by the Progetto Sisma S.r.l. company, uses galvanized steel elements and insulating panels [33].

The use of the components is regulated at the European level by the Eurocode 3 standard [34] (for steel profiles) or Eurocode 9 [35] (for aluminium alloy profiles), which provide designers with guidelines for the design and verification of members and connections along with the current Italian Technical code [36,37].

In this paper, a new, innovative, and sustainable integrated retrofitting technique based on the use of extruded aluminium profiles is discussed. The system under study, named MIL15.s [38,39], has been tested by means of two experimental tests conducted at the INCERC laboratory in the city of Timișoara (Romania). The envelope system is made up of vertical aluminium alloy elements and sandwich panels. Further details will be provided in the paragraph dedicated to the description of the system.

In the first phase, the out-of-plane behaviour of a masonry panel ($1.20\text{ m} \times 2.40\text{ m} \times 0.6\text{ m}$) was evaluated. Then, the same cracked wall was consolidated through the application of the base aluminium profile connected using chemical anchors. The results obtained after the retrofitting pointed out the benefits of the system, which allowed for the achievement of a greater horizontal force without any lesions on the aluminium components. Finally, after a numerical simulation was set on the 3Muri computer program, a comparison between the results from the software and the real test was performed. It evidenced good calibration, achieving values very close to the experimental ones and highlighting, therefore, the reliability of the numerical tool.

2. Materials and Methods

The experimental test was conducted at the National Institute for Research and Development in Constructions (INCERC) in Timișoara, a city in the western part of Romania, and was carried out in two different phases.

In the first step, the trial was performed on an unconsolidated brick masonry wall, while in the second one, the same cracked wall was reinforced by adding the extruded aluminium profiles of the system under investigation. By carrying out the first phase and damaging the masonry panel, a more realistic situation was attained. Indeed, in most cases, the consolidation interventions are designed for existing masonry constructions which have been damaged by seismic events.

The wall on which the test was conducted was made by combining two masonry panels. Each panel had a size of $1.20\text{ m} \times 1.20\text{ m}$ and a thickness of about 60 cm. After joining them with mortar, the final wall had a width of 1.20 m, a height of 2.40, and a thickness of 60 cm from the base to the top. Figure 1 shows how the final wall was obtained.

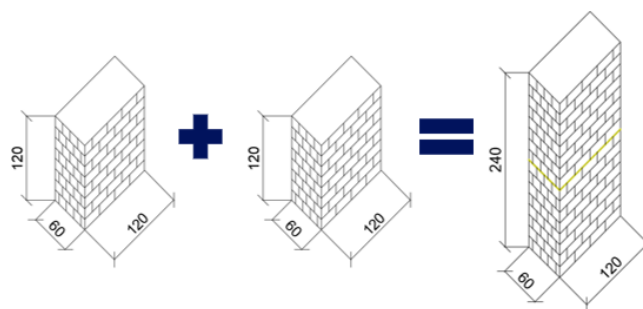


Figure 1. The masonry wall on which the experimental tests were conducted.

In Figure 2, the real base masonry panel ($1.20\text{ m} \times 1.20\text{ m}$) is represented.



Figure 2. Real base panel: 1.20 m × 1.20 m.

The final masonry wall obtained was anchored at the base using hooks and connected at the top to a metal frame with tie rods. It is depicted in Figure 3.



Figure 3. The masonry wall obtained from the union of two panels.

Once the curing time of the mortar joint between the two base panels had elapsed, the setup for the test was defined, and the loads were applied. Particularly, the wall was subjected to a constant stabilizing axial load equal to 100 kN, and it was pushed by a variable horizontal force applied corresponding to the joint between parts in order to evaluate its out-of-plane behaviour.

The adopted static scheme, which included the applied forces and the predicted out-of-plane mechanism deformation (shown with a dashed grey line), is illustrated in Figure 4.

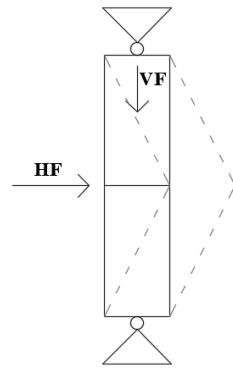


Figure 4. The adopted static scheme.

Figure 5 displays the entire setup defined for the test. The vertical load was imposed by a load actuator through a wooden spreader beam. The horizontal force was applied using a jack corresponding to the middle joint. It is also possible to see the tie rods used to secure the top of the masonry panel.

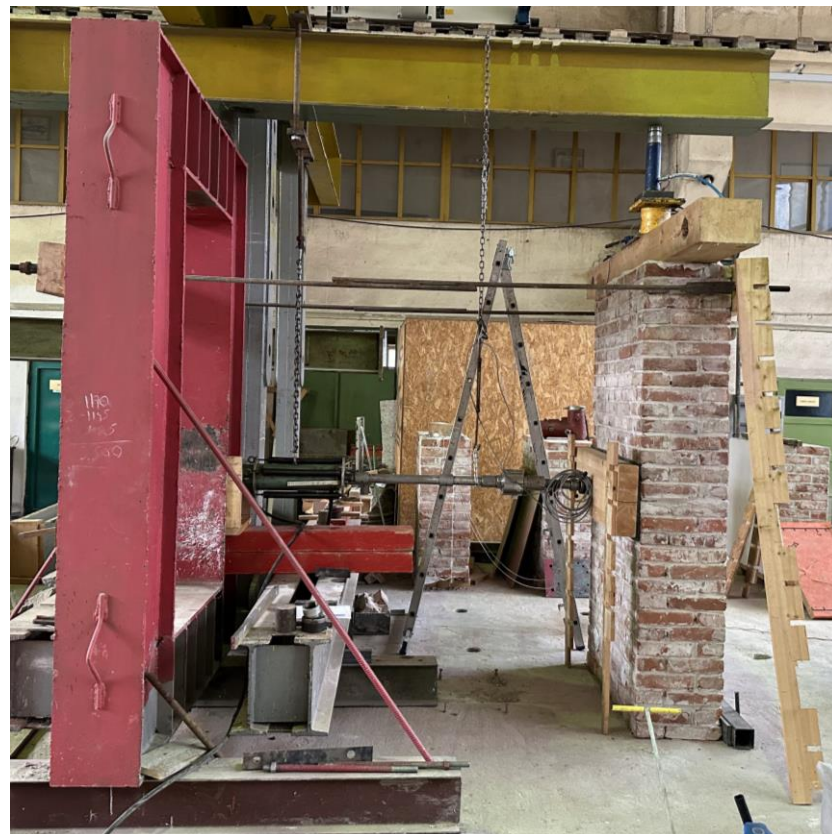


Figure 5. The setup for the experimental test.

The Evaluation of the Compression Strength

Before testing the entire masonry panel, a compression test was performed on three samples of single bricks (Figure 6) in order to evaluate their compression resistance [40].

The ceramic elements were derived using a semi-controlled manufacturing process, underwent uneven firing, and were not homogeneous in composition. They were cut in half before being tested to intercept solid surfaces. The mortar was laid on the first half, which had a perfect foreground, while the second half was rotated 90° with respect to the cutting section.



Figure 6. Samples of bricks.

Following the hardening of the mortar, the samples were cured, then tested to obtain the compression resistance. The results are given in Table 1.

Table 1. Results of the test performed on the bricks.

Sample	Side 1 [mm]	Side 2 [mm]	Force [daN]	Compression Resistance [N/mm ²]
B1	148	147	18,080	8.47
	150	146		
	148	138		
B2	144	146	23,750	11.30
	143	149		
	144	144		
B3	144	140	19,310	9.56
	147	139		
	141	142		

3. Test on the Unreinforced Masonry Wall

Once the mechanical properties concerning the compression strength had been attained and after the curing time for the mortar had elapsed, it was possible to carry out the experimental test.

In order to monitor both horizontal and vertical displacements, three sensors were inserted and placed near the joint between the two panels, as displayed in Figure 7.

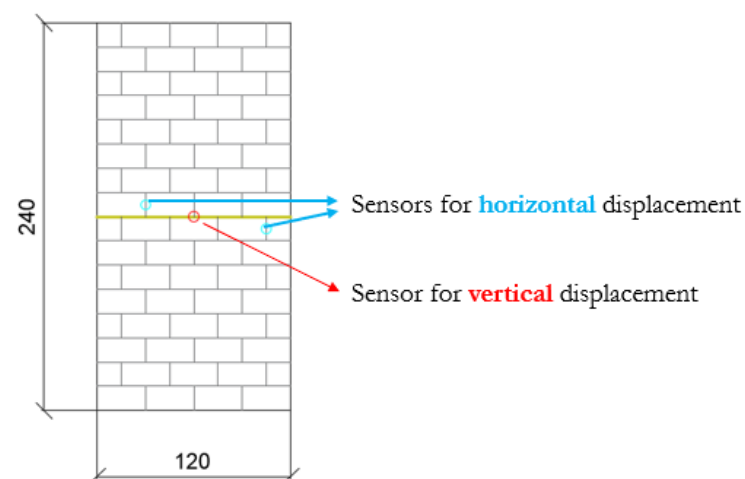


Figure 7. Placement of the sensors.

The sensor to assess vertical displacements was placed at the joint between the two panels to evaluate the opening of the crack. In close proximity to the joint, the other two sensors needed to measure horizontal displacements were inserted.

As mentioned above, during this first analysis phase, the test was conducted on the unconsolidated masonry wall to obtain a crack pattern close to that of a real case.

After the axial load equal to 100 kN was applied to the top of the wall, the phase of horizontal thrusting started.

At the end of the test, the maximum horizontal value of the force reached was of about 65.94 kN, with a corresponding ultimate displacement of 12.59 mm.

In Figure 8, it is possible to note the relationship between the increasing horizontal force and the corresponding displacement monitored near the middle of the wall.

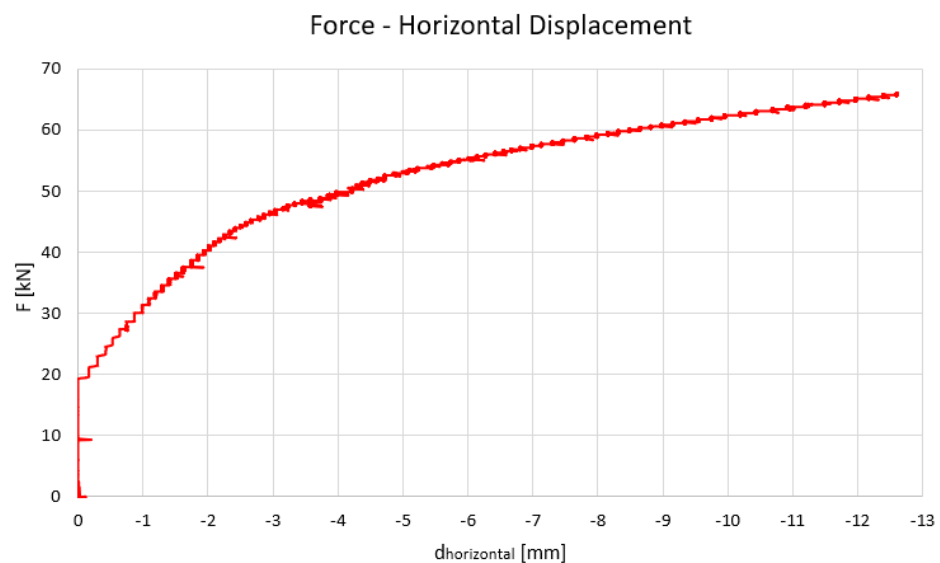


Figure 8. Graph of force—horizontal displacement.

In Table 2, the test results are tabulated. They show how, at each horizontal displacement, the value of the thrusting force and the corresponding vertical displacement increased. In the initial phase, the growth of the force was faster and greater, while in the last steps, it decreased until drawing on the maximum bearable value.

Table 2. Test results.

Phase 1—Test on Unreinforced Masonry Wall (1.20 m × 1.20 m × 0.60 m)		
Horizontal Displacement [mm]	Vertical Displacement [mm]	Horizontal Force [kN]
1	0.02	13.67
2	0.64	26.81
3	1.19	35.14
4	2.11	49.86
5	2.27	52.94
6	2.53	55.13
7	2.71	57.47
8	2.88	59.26
9	3.08	60.85
10	3.36	62.42
11	3.51	63.53
12.59 Ultimate Hor. Displ.	3.89 Ultimate Vert. Displ.	65.94

On contrary, Figure 9 displays the trend of the horizontal force and the vertical displacement, which achieved a maximum value of 3.89 mm. It corresponded to the crack which appeared in the centre line and is depicted in Figure 10.

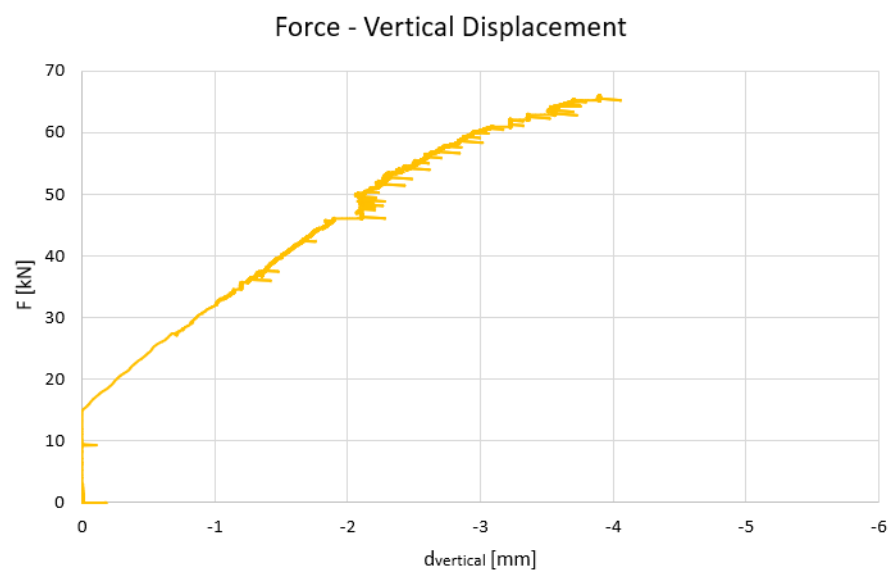


Figure 9. Graph of horizontal force—vertical displacement.



Figure 10. Crack in correspondence to the middle joint.

As it is possible to point out from Figure 11, the failure mechanism stood as a vertical bending mechanism, since the wall was bounded at its extremities.

Table 3 summarizes the final results attained in this first phase for all the parameters monitored.

Table 3. Final results of the first step of the experimental test.

Phase 1—Test on Unreinforced Masonry Wall (1.20 m × 2.40 m × 0.60 m)		
Horizontal Force [kN]	Horizontal Displacement [mm]	Vertical Displacement [mm]
65.94	12.59	3.89



Figure 11. Vertical bending failure mechanism.

4. The Retrofitting System: The MIL15.s Seismic Energy Coat

Once the first phase of the experimental test had been completed, in order to perform the second stage, the consolidation system was applied. It is an innovative, lightweight, sustainable, and integrated solution. This means that it simultaneously ensures an improvement in both the seismic and energy performances of the building. This is due to the presence of aluminium alloy exoskeletons combined with insulation panels. The former serves to absorb seismic actions, while the latter is aimed to reduce thermal dispersion coming from indoor environments.

The system under investigation is called MIL15.s, and it is manufactured by an Italian company, the TM Group S.r.l., which patented the coat in May 2022. Apart from improving the seismic behaviour, its use has many other advantages. First of all, since it consists of prefabricated elements, it is very easy and quick to assemble; this aspect reduces both costs and time on site. Moreover, since the coating system is applied externally in correspondence with the free facades of the structure, it avoids interrupting the internal activities. A view of the system is displayed in Figure 12.

The system consists of extruded aluminium alloy profiles (Element nr. 1 in Figure 12), which are placed at variable distance one to each other (approximately 1 m) and fixed to the perimeter masonry walls using chemical anchors (El. Nr. 6 in Figure 12) with diameters of about 12 mm. The thermal insulation panel (El. Nr. 8 in Figure 12) is inserted in the empty space between two consecutive vertical profiles. Generally, it is a sandwich panel with trapezoidal external sheeting, and it is anchored using self-drilling screws. The insulating material could be rock wool or polyurethane. Finally, the integrated MIL15.s system is completed with the placement of the closing profiles (El. Nr. 2 in Figure 12). There are other components, such as the EPDM tape and thermal insulator (El. Nr. 5 and 3, respectively, in Figure 12), that are inserted to avoid any thermal dispersions. The resulting system can be completed with various external claddings, for instance, with either plaster or a ventilated façade.

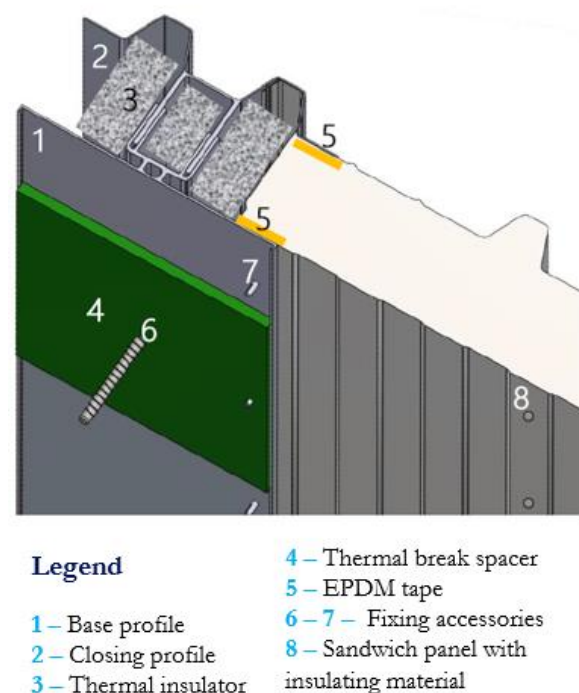


Figure 12. The MIL15.s system.

The aluminium alloy used for the manufacturing of the profile was alloy 6060—T6, whose main mechanical properties are indicated in Table 4.

Table 4. Mechanical properties of aluminium alloy used for the profiles.

Alloy	Characteristic Value of 0.2 Proof Strength $f_{0.2}$	Ultimate Tensile Strength f_u	Breaking Elongation	Buckling Class	Durability Class
Al–Si–Mg	150 MPa	190 Mpa	8%	A	B

This alloy consists of magnesium and silicium and exhibits excellent mechanical properties in structural applications. The T6 term indicates the treatment of the alloy. In this case, it corresponds to a heat treatment with hardening and subsequent artificial ageing.

Choosing aluminium for the system profiles is based on its main benefits. Firstly, it is a light material with a low specific weight, three times lower than that of steel. It shows an exceptional resistance against corrosion due to the formation of a thin, protective aluminium oxide layer on the surface of the element [41–45]. It also has a high durability over time. In the end, one of the most important properties of the aluminium alloy material is its sustainability. Indeed, structural aluminium is fully recyclable without losing its quality. Its recyclability is very important from environmental and economic points of view. It is easy to recycle due to its light weight, which in turn makes it easier to be transported. The production of new aluminium alloy elements from recycled components requires a minor amount of energy consumption and emits less greenhouse gas [46–49].

An additional Interesting aspect to consider In relation to this type of consolidation system is its cost. The cost of the integrated seismic energy coat depends on various parameters. Among these, one of the main factors is the location of the building to be consolidated, since this affects the transportation cost. The final value is also influenced by the materials used for the profiles (steel or aluminium alloy) and the thermal insulation solution.

The starting price is around EUR 30–35/sqm, with additional costs for transportation and installation at the construction site. Therefore, the final price can reach approximately EUR 200–250/sqm.

5. Second Part of the Experimental Test: The Consolidated Wall

In this preliminary experimental test, only the contribution of aluminium alloy profiles and the related connection systems to the wall were assessed for consolidation purposes. In a subsequent analysis phase, the contribution of the whole system (aluminium alloy profiles and sandwich panel) will be analysed, aiming at ascertaining the system's benefits from a seismic viewpoint. In order to evaluate the behaviour of the masonry panel reinforced with the extruded aluminium profiles, they were applied at 90 cm one to each other and connected to the wall using chemical anchors 12 mm in diameter, as shown in the scheme of Figure 13.

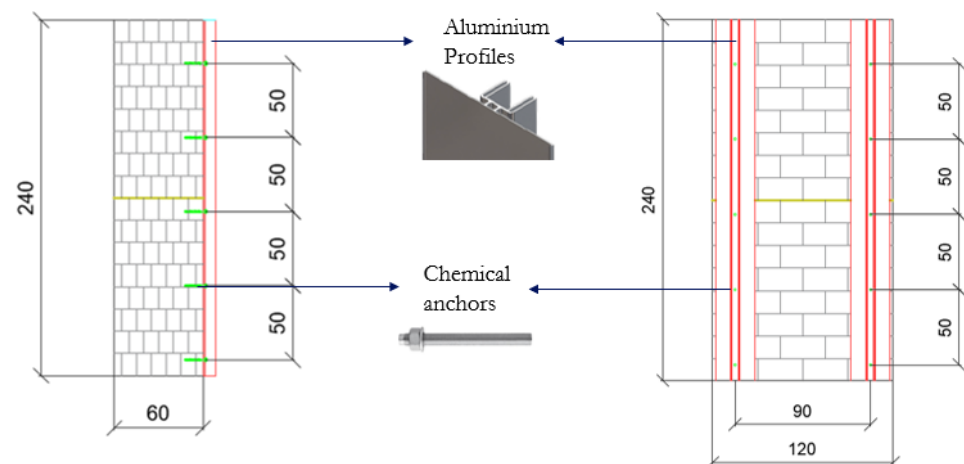


Figure 13. Scheme of the application of the retrofit system.

The reinforced specimen is revealed in Figure 14.



Figure 14. Masonry wall reinforced with aluminium profiles.

In Figure 15a, the details of the imperfect adhesion between the masonry support and the aluminium profiles is depicted.



Figure 15. Imperfect adhesion between masonry support and aluminium alloy profiles; (a) Lateral View; (b) A detailed view of the imperfect adhesion.

Afterwards, the masonry wall was set up under the same conditions described above for the first phase of the experimental test. The test was repeated by means of two loading–unloading cycles, as shown in Figure 16.

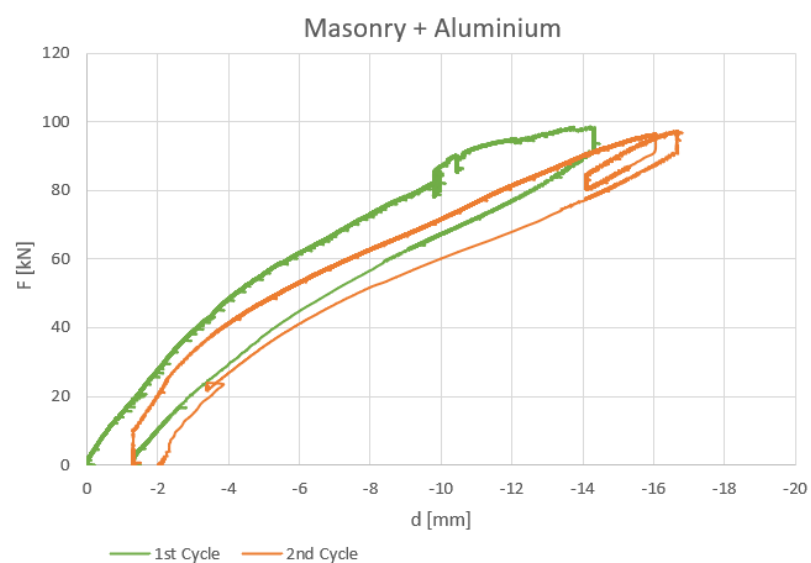


Figure 16. Hysteretic curve.

During the first loading phase, the masonry wall was able to withstand a maximum horizontal force equal to 98.32 kN with an ultimate displacement of 14.20 mm. At the end of the unloading phase, the panel showed a residual deformation of 1.3 mm.

Figure 17 shows the relationship between the thrusting force and horizontal displacement during the first cycle of loading.

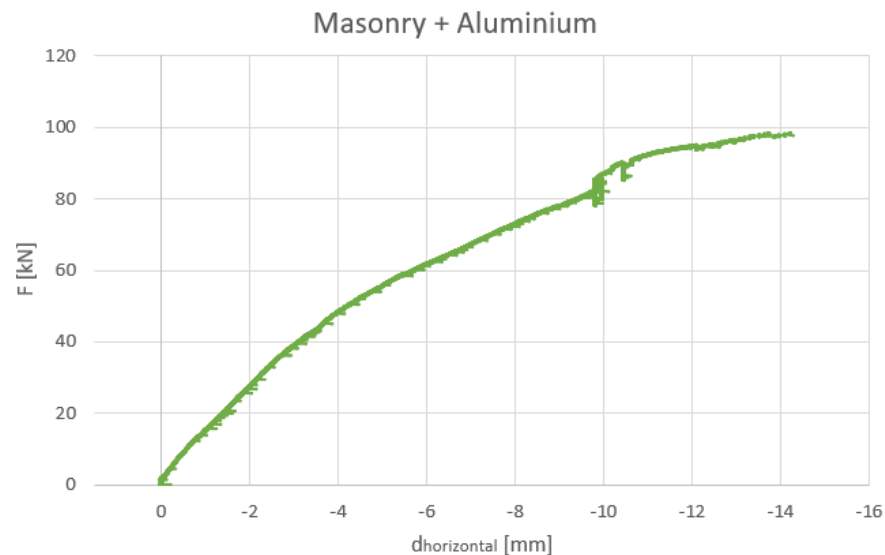


Figure 17. First cycle—loading phase.

The relationship between the maximum horizontal force and the vertical displacements measured in the centre of the wall is depicted in the diagram of Figure 18, where it is apparent that the vertical displacement reached a value of 8.89 mm.

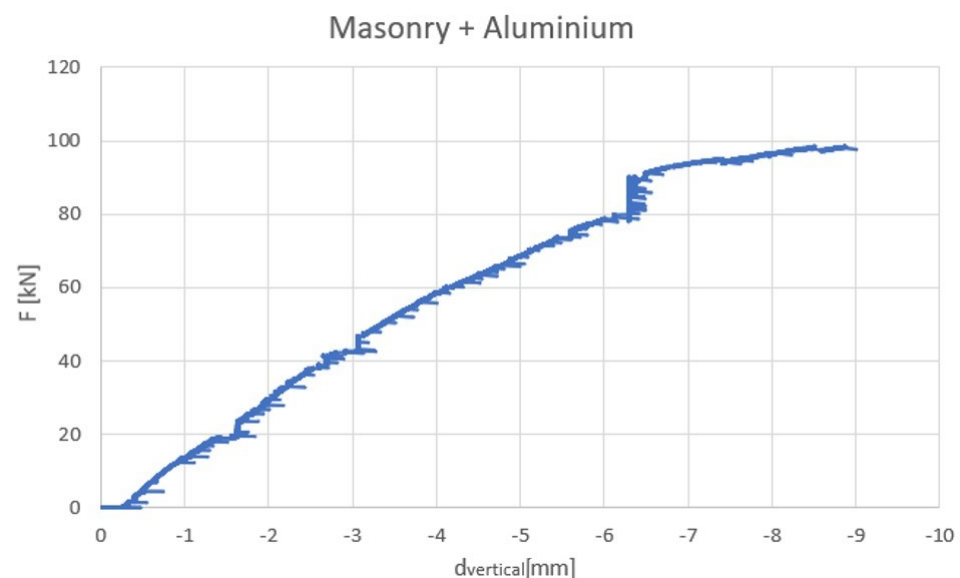


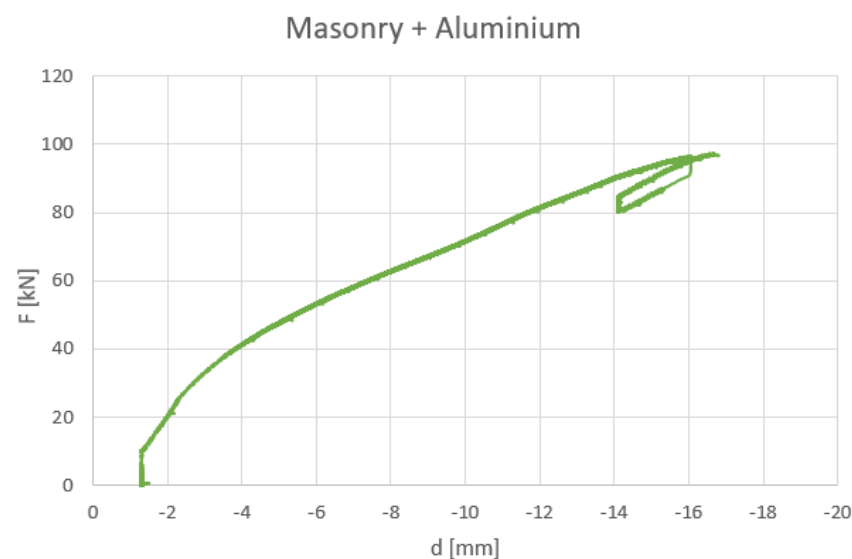
Figure 18. Horizontal force—vertical displacement graph.

Table 5 contains the test results relating to the first loading phase. Also, in this second analysis phase, in the initial loading step for each horizontal displacement, the force increased more and then settled down until the maximum force was reached.

Table 5. Test results—first cycle.

Phase 2—Test on Reinforced Masonry Wall (1.20 m × 2.40 m × 0.60 m)		
Horizontal Displacement [mm]	Vertical Displacement [mm]	Horizontal Force [kN]
1	1.11	15.38
2	1.93	27.68
3	2.59	38.88
4	3.22	48.42
5	3.77	55.74
6	4.33	61.77
7	4.87	67.31
8	5.40	72.90
9	5.94	78.15
10	6.29	87.05
11	6.68	92.36
12	7.33	94.81
13	8.02	96.47
14.20	8.89	98.32

Then, there was the second cycle, in which a maximum value of the force equal to 97.09 kN was attained. The corresponding ultimate displacement was of 16.66 mm. The graph is represented in Figure 19.

**Figure 19.** Second cycle—loading phase.

During the second cycle (Table 6), the original horizontal displacement was equal to 1.3 mm, which corresponds to the residual deformation at the end of the unloading phase of the first cycle. The maximum horizontal movement reached during this cycle was 16.66 mm under a force of 97.08 kN.

In both cycles, the positive effect of the presence of the aluminium components was evident, which ensured a remarkably high horizontal force value.

This positive influence can also be demonstrated by the curves before and after the intervention, which are plotted together in Figure 20.

In the end, another interesting result was connected to the behaviour of the aluminium profiles. They did not show any lesions, and the holes realized for the chemical anchors maintained their circular shape without any bearing mechanism, as shown in Figure 21.

Table 6. Test results—second cycle.

Phase 2—Test on Reinforced Masonry Wall (1.20 m × 1.20 m × 0.60 m)		
Horizontal Displacement [mm]	Vertical Displacement [mm]	Horizontal Force [kN]
1.30	2.07	10.17
2	2.24	20.20
3	2.77	33.01
4	3.29	41.24
5	3.85	47.58
6	4.39	53.23
7	5.00	58.12
8	5.66	62.75
9	6.27	67.10
10	6.89	71.60
11	7.50	76.56
12	8.12	81.37
13	8.79	85.63
14	9.50	90.04
15	10.15	93.45
16.66	11.39	97.08

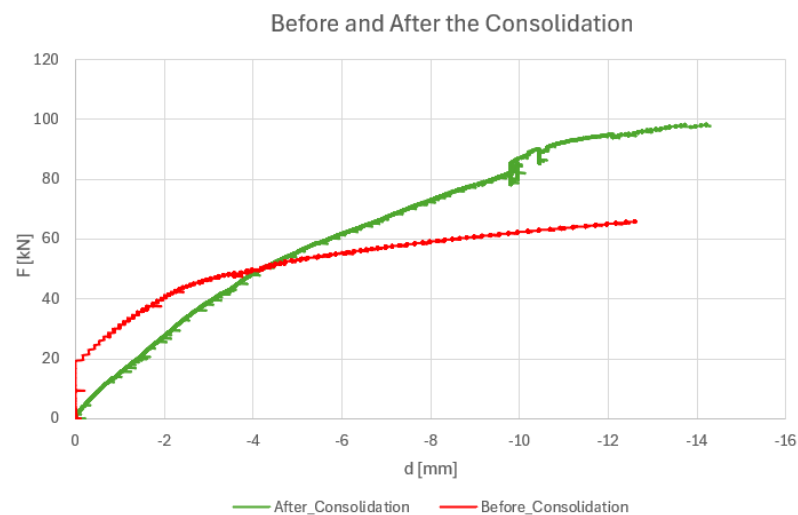


Figure 20. Comparison of the curves.



Figure 21. The aluminium profiles after the experimental test.

In Table 7, a comparison of the results before and after the application of the aluminium profiles on the masonry wall is reported. In terms of horizontal force, there was an improvement equal to 49%.

Table 7. Comparison of the results.

Phase 1—Test on Unreinforced Masonry Wall (1.20 m × 2.40 m × 0.60 m)		
Horizontal Force [kN]	Horizontal Displacement [mm]	Vertical Displacement [mm]
65.94	12.59	3.89
Phase 2—Test on Reinforced Masonry Wall (1.20 m × 2.40 m × 0.60 m)		
Horizontal Force [kN]	Horizontal Displacement [mm]	Vertical Displacement [mm]
98.32	14.20	8.89

6. Comparison with the Numerical Simulation

In the last part of the work, a comparison with the results obtained from the experimental test was carried out by conducting a numerical simulation. Particularly, the 3Muri computer software, Version 14, given by the STA.DATA company, was used.

It is a numerical program which can be used for both the verification and design of existing and new structures. In addition, it allows not only masonry structures, but also reinforced concrete constructions with different uses, to be analysed, such as residential buildings or industrial ones, and even monumental edifices with high cultural value [50].

This tool is based on a Frame by Macro-Element (FME) approach which divides each masonry panel in three components: masonry piers, spandrels, and rigid nodes.

The comparison was executed for both configurations. For this reason, a masonry panel with the same mechanical and geometrical dimensions equal to 1.20 m × 2.40 m × 0.60 m was created. Once the vertical loads had been applied, the analyses were performed. They allowed the ultimate horizontal displacement to be derived in correspondence with the middle point represented by Node 13, which is displayed in Figure 22, and the relative force. The final results are illustrated in Table 8.

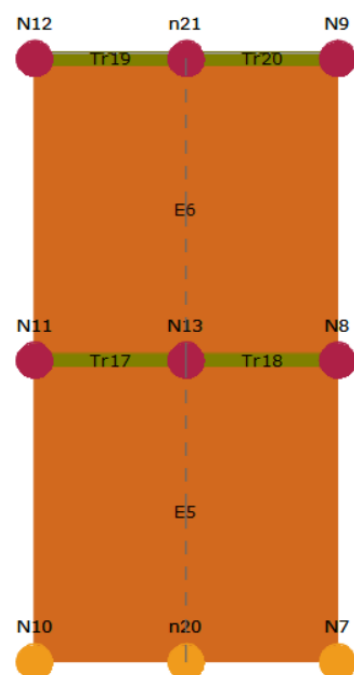
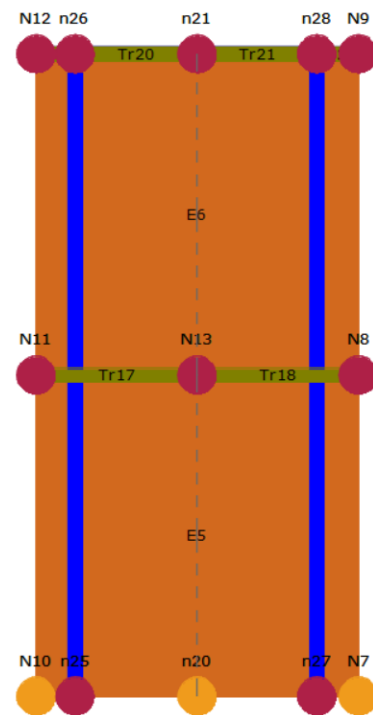


Figure 22. Masonry panel on 3Muri software—before consolidation.

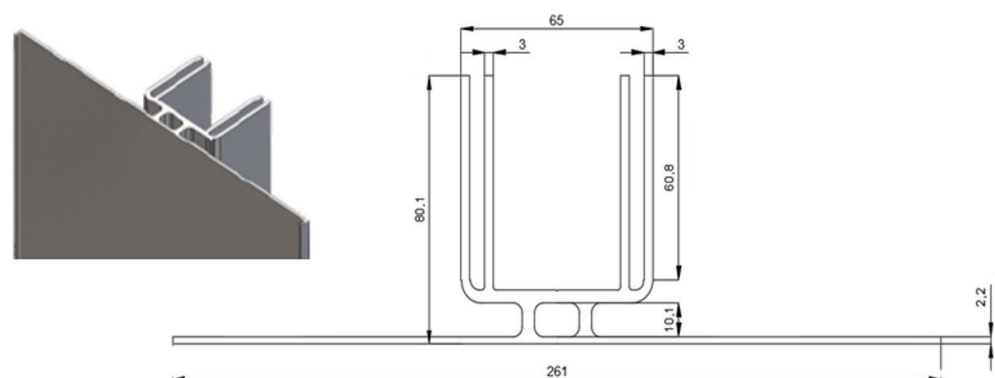
Table 8. Simulation results—unconsolidated state.

Horizontal Force [kN]	Horizontal Displacement [mm]
66.5	14.2

In order to complete the comparison with the second part of the experimental test, the extruded aluminium base profiles were inserted into the 3Muri model, as can be seen in Figure 23 (blue elements).

**Figure 23.** Masonry panel on 3Muri software—after consolidation.

They were modelled with their original shape, which is represented in Figure 24.

**Figure 24.** The shape of the base profile belonging to the MIL15.s system.

In Table 9, the results regarding the second part of the simulation are inserted. In this case, an ultimate displacement equal to 17.3 mm was attained in correspondence with the same point (Node 13).

Table 9. Simulation results—consolidated state.

Horizontal Force [kN]	Horizontal Displacement [mm]
88.8	17.3

Lastly, Table 10 summarizes the comparison between the results obtained by carrying out the experimental test and the ones derived from the numerical simulation performed with the 3Muri program. The values obtained in both conditions, unconsolidated and consolidated, are very close to each other and demonstrate the reliability of the calculation code used for the numerical simulation.

Table 10. Comparison of the results between experimental test and numerical simulation.

1st Phase—Unconsolidated Masonry Panel—Experimental Test	1st Phase—Consolidated Masonry Panel—Numerical Simulation
Horizontal Force [kN] 65.94	Horizontal Force [kN] 66.5
Horizontal Displacement [mm] 12.59	Horizontal Displacement [mm] 14.2
2nd Phase—Consolidated Masonry Panel—Experimental Test	2nd Phase—Consolidated Masonry Panel—Numerical Simulation
Horizontal Force [kN] 98.32	Horizontal Force [kN] 88.8
Horizontal Displacement [mm] 14.20	Horizontal Displacement [mm] 17.3

7. Conclusions

The paper deals with the evaluation of the effectiveness of an innovative integrated seismic energy coating system through the execution of an experimental test at the INCERC Laboratory of Timișoara (Romania).

In the first part of the work, the importance of the interventions able to increase the seismic and energy behaviour of the existing structures was discussed. In order to fulfil these goals, the use of metal exoskeletons (made of cold-formed steel elements or aluminium alloy components) coupled with insulating panels represented one of the best solutions among the different available consolidation techniques.

The MIL15.s system, manufactured by the Italian company TM Group S.r.l., was the integrated system under investigation in the current paper. It consists of aluminium alloy elements connected to the masonry through chemical anchors and completed with the insertion of thermal insulating panels. In order to evaluate its influence, some preliminary experimental tests were conducted in two different phases.

During the first stage, the test was performed on a masonry wall with dimensions equal to $1.20 \text{ m} \times 2.40 \text{ m} \times 0.60 \text{ m}$, and it was aimed to examine the out-of-plane behaviour. The wall was subjected to a constant vertical force of 100 kN and thrust by a variable horizontal force. At the end of this first phase, a maximum value of 65.94 kN was attained for the horizontal force, with a corresponding value of 12.56 mm for the displacement.

After performing the test on the unconsolidated wall, it was reinforced by means of the extruded aluminium alloy base profiles of the MIL15.s coating system.

Unexpectedly, surpassing our predictions and initial hypotheses, in the second phase, considering the contribution of only aluminium alloy profiles, a maximum horizontal force equal to 98 kN was reached with a displacement of 16.56 mm.

The comparison of the two states reveals the positive effects resulting from the placement of the profiles, which did not show any cracks or significant deformation, as was hypothesized before experimentation. In a subsequent experimental phase, even better results could be achieved by evaluating the panel's response with the entire system under investigation.

Therefore, it is possible to affirm that the system is an effective solution to avoid out-of-plane mechanisms of masonry walls under seismic actions.

In the end, by performing a numerical simulation using the 3Muri computer software, a comparison was made between the results obtained from the program and the real test. Both scenarios provided results close to each other, demonstrating the validity of the numerical software in predicting the seismic behaviour of the consolidated wall.

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