JOURNAL OF APPLIED ENGINEERING SCIENCES
ISSN: 2247-3769 / e-ISSN: 2284-7197

VOL. 5(18), ISSUE 1/2015
ART.179, pp. 69-74

DE GRUYTER
OPEN

EVALUATION OF SHEAR CAPACITY FOR BRICK MASONRY WALLS

Eva Partene [a, *], Luminita Fekete-Nagy [a], V. Stoian [a]

[a] Politehnica University Timisoara, Department of Civil Engineering and Building Services,
2nd T. Lalescu, Timisoara, Romania, *e-mail: eva.partene@student.upt.ro

Received: 13.03.2015 / Accepted: 01.04.2015 / Revised: 28.04.2015 / Available online: 31.05.2015

DOI: 10.1515/jaes-2015-0009

KEY WORDS: Masonry Walls, Ceramic Block With Hollows, Cyclic In-Plane Loads

ABSTRACT:

The papers presents the results of an experimental program and provides valuable information regarding the behaviour of structural masonry walls built up using ceramic blocks with hollows, which represents a very common system for low-rise residential buildings, up to 4 stories, depending on the seismic acceleration on site. A number of six masonry walls where tested in bear state being subjected to constant vertical loading and to cyclic in-plane horizontal loads. The main objective was to determine the shear capacity for unreinforced masonry walls and reinforced masonry walls. The experimental results were also useful to determine the contribution of the reinforcing of the masonry walls with concrete columns. The comparison between unreinforced masonry and reinforced masonry has a great importance due to the fact that the Romanian Seismic Standards have imposed the reinforcement in seismic areas for building with more than 1 storey. Further studies will be conducted on strengthening the masonry walls using FRP materials.

1. INTRODUCTION

Masonry is the oldest building material used, with a very good behaviour in time, except for the seismic areas with important ground accelerations. Evan though the behaviour of masonry in seismic areas is not very well known, this type of structure remains the most common, especially for residential buildings.

In the last twenty years the scientific community began to show more interest in advanced testing of masonry walls subjected to horizontal loads in-plane and out of plane (Laurenco, 1998).
Due to the increased interest, the standards became more elaborate and have a greater understanding for the failure mode of this type of materials (Partene, 2013).

Another important issue is the evaluation of seismic vulnerability of existing buildings, due to the number of buildings constructed before the existence of seismic codes and before the knowledge of the material properties. The experimental testing of masonry elements is more needed in this cases and it is the most viable method to determine the mechanical properties and the failure modes for different wall configurations, using a variation of material types (Magenes, 1992).

After evaluating the seismic vulnerability in bear state, another important matter is the strengthening of the masonry using different materials. It is impossible to conceive the strengthening of masonry structures without fully understanding the behaviour in bear state under seismic actions. A practical approach like using the experimental testing is essential as masonry structures are characterized by a complex behaviour under dynamic loads. Also the disadvantage of masonry is that it is more predisposed to damage than reinforced concrete structures or steel structures (Plesu, 2011).

Mechanical properties of masonry are reasonable for compressive strength, but very low for tensile strength. Masonry also has a very good behaviour for gravitational loads but the most important disadvantages are related to the relatively high weight of the structure, execution at high costs and especially reduced resistance to cyclic horizontal loading (Secula, 2003).

For a better understanding of the behaviour under cyclic horizontal loads of the masonry structural walls, this paper describes an experimental program for determination of the shear capacity for unreinforced masonry (URM) and reinforced masonry (RM) panels.

* Corresponding author.

2. EXPERIMENTAL PRGRAM

2.1 Material Characterization

The material properties where partially determined by performing tests and partially from the producers characteristics certificates. The ceramic blocks used are type Porotherm 25, which have the dimensions: length of 375 mm, width of 250 mm and height of 238 mm, with air gaps of 48% of the section area. The material properties can be seen in Table 1.

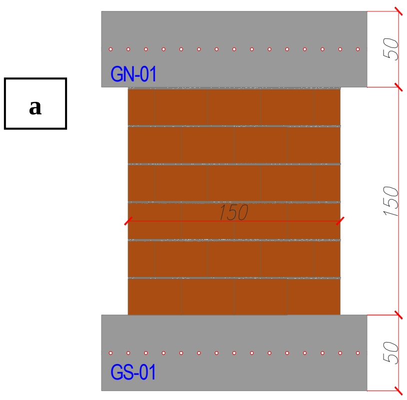
Material	Tensile strength	Compressive strength	Elastic modulus
	N/mm^2	N/mm^2	N/mm^2
Masonry	0.14	3.98	2350
Concrete C16/20	1.43	16.60	27000
Steel S235	235		210000
Steel S355	355		210000

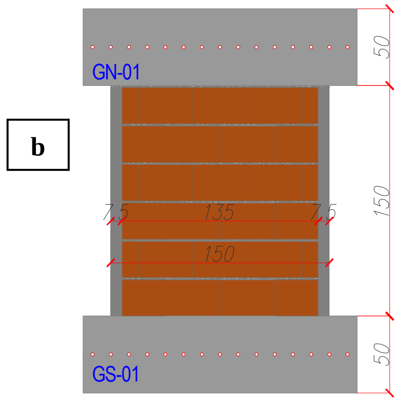
Table 1. Material properties for wall test specimens

The walls were built by a qualified brick layer, in order to not introduce additional variables such as handwork and different mortar workability that may arise from the construction of the specimens (Tumialan, 2001), using ceramic blocks with hollows, general purpose mortar M5, consisting of cement, hydrated lime and sand. The concrete columns were built using C16/20 concrete, prepared on the Concrete Laboratory from de Civil Engineering Department.

2.2 Test Specimens

Six walls with the dimensions of 1.5x1.5 m and width of 0.25 m, were tested as a part of this research program. The masonry walls specimens where built using ceramic blocks with hollows. The first specimen is built as unreinforced masonry (URM), the second one is reinforced masonry with two concrete columns on both sides (RM1) and the third is reinforced masonry with a central concrete column (RM2) as seen in Figure 1.





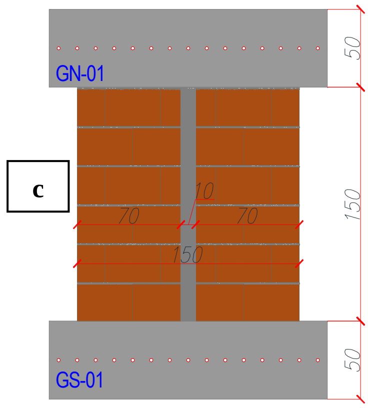


Figure 1. Test specimens (a. URM, b. RM1, c. RM2)

The horizontal and vertical reinforcing bars where placed according to Romanian Standards CR6:2013 as seen in Figure 2 (Partene, 2014).

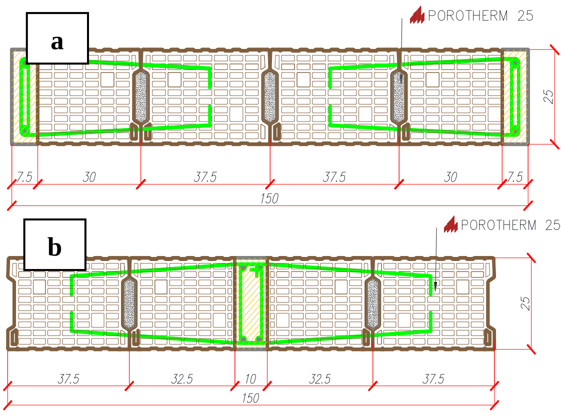


Figure 2. Reinforcement position for the reinforced masonry walls (a. URM, b. RM1, c. RM2)

2.3 Test Setup

The experimental tests were performed on six masonry walls, two specimens for the three types described. The experimental stand has three essential parts: a reaction frame for the horizontal load, a reaction frame for the vertical load and a sliding frame as shown in Figure 3.

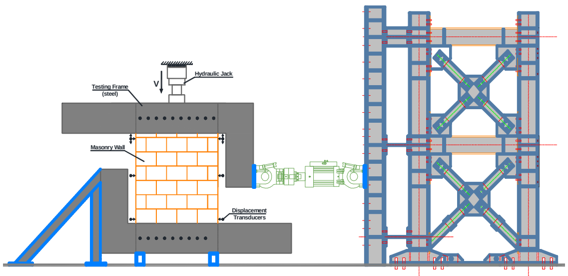


Figure 3. Experimental stand and loading scheme

The instrumentation consisted on 12 displacement traducers and 2 pressure traducers in order to determine the drift, the applied forces and to observe if at any point the wall has out of plane displacements. In order to compensate for the lateral stability, a guidance frame was built as a restraint, placed at 3 mm away from the sliding frame, so that the wall could translate freely, eliminating friction until guidance frame was needed (Durham, 2004).

In order to obtain the shear capacity of the walls, the walls were subjected to constant vertical load, to simulate the loads from upper storey of a building and a cyclic horizontal load.

For the loading scheme was used a vertical hydraulic jack, manually controlled, placed on the top surface of the loading beam for applying of a constant vertical load. For the horizontal load a hydraulic actuator was fixed on the reaction frame at one end and on the sliding frame at the mobile end. This actuator was controlled by software on the computer (Zhou, 2013).

The horizontal load was applied by repeating cycles of increasing drift ratio of at least 0.25% (displacement control) as seen in Figure 4.

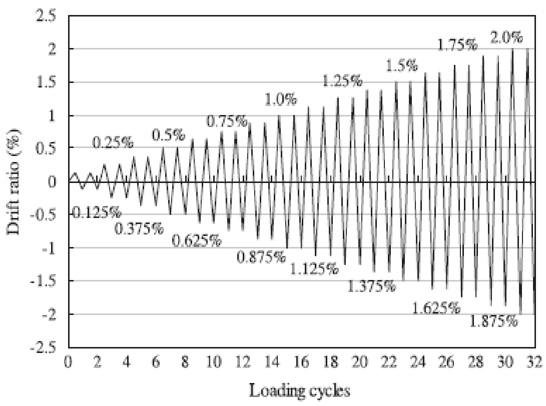


Figure 4. Cyclic testing protocol used

The horizontal load was increased until the collapse mechanism was activated (Tena-Colunga, 2009).

2.4 Test Results

Failure mode for in-plane masonry walls occurs when the walls are effective in transmitting the horizontal loads to the foundations. This is the wanted situation and it proves that the building has a good spatial configuration. (Dogariu, 2009)
The walls from our experimental program where tested for in-plane load and the walls had an in-plane failure mode as shown in Figure 5 (Petersen, 2009).

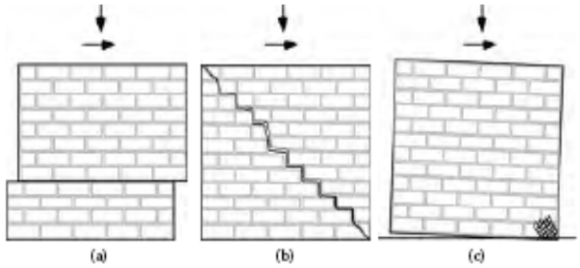


Figure 5. In plane failure modes for masonry walls
(a. sliding, b. diagonal cracking, c. flexural failure)

The six masonry wall specimens from our experimental program failed in the most common failure mode, which is the pure shear failure mode: diagonal cracking. The tests were performed until the walls failed suddenly along a diagonal crack or a diagonal along the head and bed mortar joints, when they reached their diagonal tensile strength (Ismail, 2011).

For the first wall specimen type we have the force-displacement diagram as seen in Figure 6.

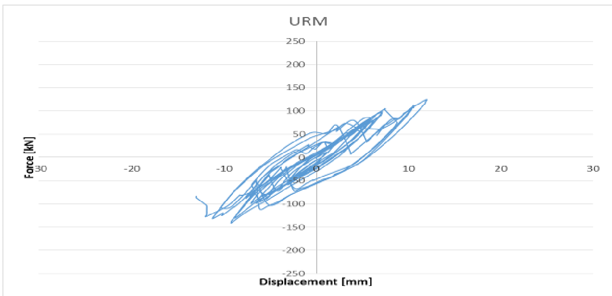


Figure 6. Force-displacement diagram for URM specimens

The first unreinforced specimen failed in a single diagonal and the cracks where joints formed mostly in head and bed mortar.

For the second specimen we reduced the initial drifts and the wall failed in both diagonals, mostly in the ceramic blocks. The masonry walls specimens failed as seen in Figure 7.

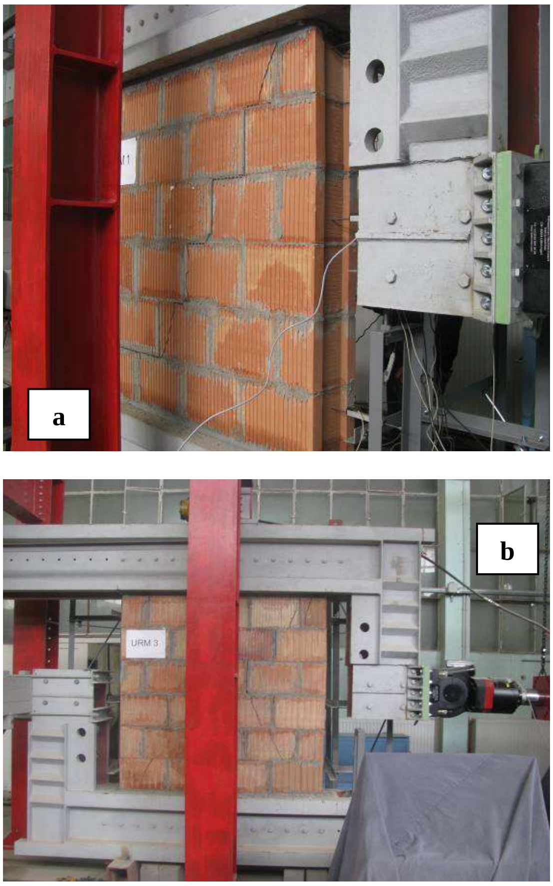


Figure 7. Failure mode for URM specimens
(a. URM1, b. URM3)

For the second wall specimen type the force-displacement diagram can be seen in Figure 8.

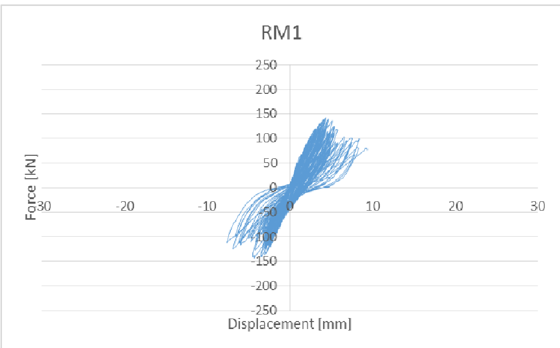


Figure 8. Force-displacement diagram for RM1 specimens

The RM1 specimen failed in head and bed mortar joints with important opening for the head mortar joints, due to the lateral concrete columns. The cracks followed both diagonals of the walls as seen in Figure 9 (Porto, 2010).

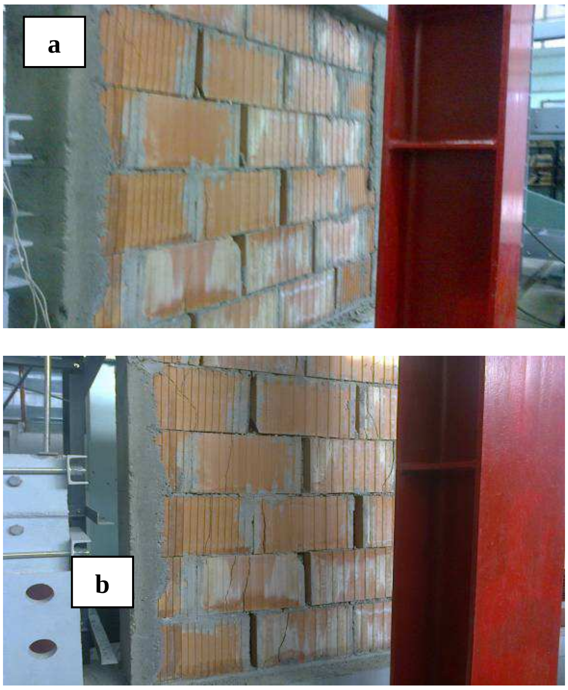


Figure 9. Failure mode for RM1 specimens (a. RM1, b. RM1-1)

For the RM2 specimen the force-displacement diagram can be seen in Figure 10.

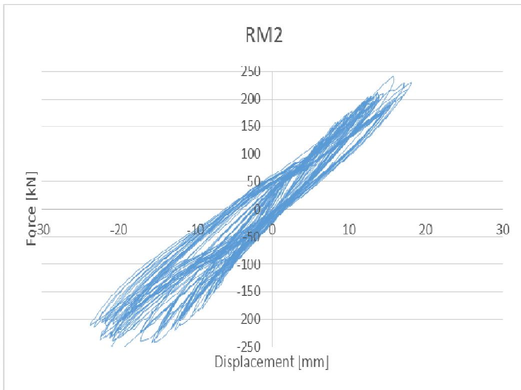


Figure 10 . Force-displacement diagram for RM2 specimens

For the RM2 specimen with one concrete column in the middle, the failure mode was also in diagonals, but this time mostly in the ceramic blocks as seen in Figure 11.

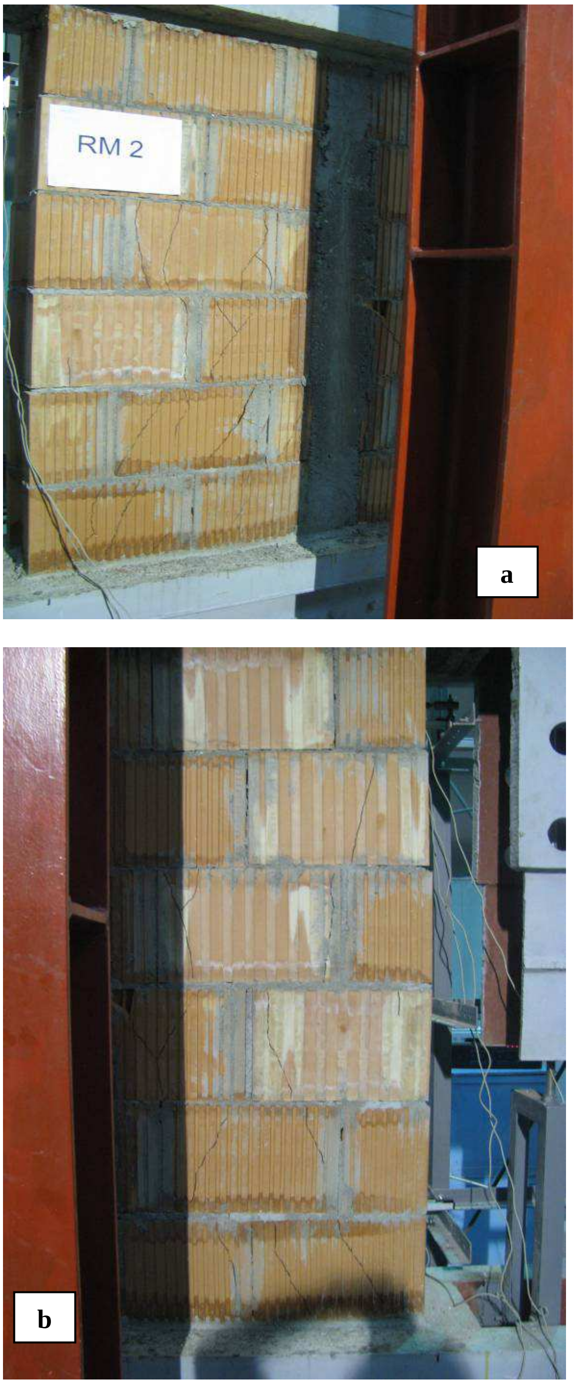


Figure 11. Failure mode for RM2 specimens
(a. RM2, b. RM2-1)

This type of wall configuration was the most efficient, with substantially increased shear capacity, in comparison with the other two wall type specimens.

3. CONCLUSIONS

The experimental program has shown an important difference between the capacities of unreinforced masonry wall in comparison with reinforced masonry. We could observe the increasing of the load bearing capacity of the reinforced masonry. This is the main reason why the Romanian Standards impose the usage of reinforced concrete columns for strengthening of the masonry in seismic areas. The reinforcement improves the behaviour under vertical and horizontal loads.
From our experimental tests can be drawn the following conclusions: the failure mode for all three wall configurations was the pure shear failure, namely the diagonal cracking, in head and bed joints or in the ceramic blocks; all the specimens showed horizontal cracks along the bed joints at the first loading stage, fact which caused the increase of the drifts. The unreinforced masonry wall reached its shear capacity along the head and bed mortar joints and in the ceramic blocks also. After the peak load, the lateral displacement increased, while the lateral loads remained almost constant. The reinforced masonry specimens RM1 failed mostly in head and bed mortar joints and had a capacity slightly increased in comparison with the unreinforced specimens. The reinforced specimens RM2 failed mostly forming the diagonal cracks in the ceramic blocks and the capacity was substantially increased in comparison with the first two specimen's types (Partene, 2014).

To assure the correctitude of the experimental tests, the experimental program will extend with 3 more wall specimens, in order to observe if the results obtained are accurate.

If we take a look at the horizontal load capacity of the 3 type of wall specimens, we can observe an important difference, as seen in Figure 11.

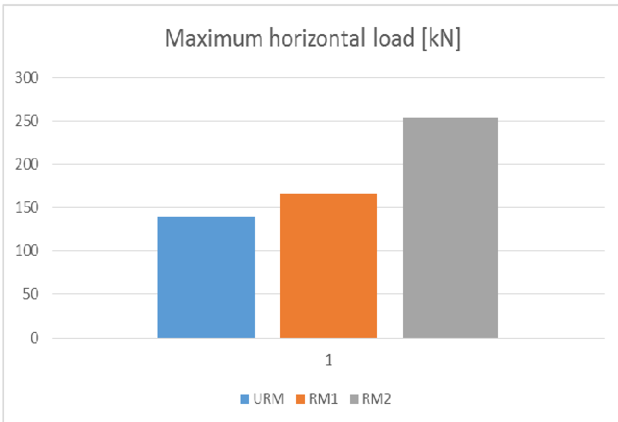


Figure 11. Maximum horizontal loads for URM, RM1 and RM2 wall specimens

For the reinforced masonry with two concrete columns RM2, the increasing of the horizontal load was only 15%, but for the reinforced specimen with one concrete column RM2, the increasing of the horizontal load is 76%.

This fact proves once again the high importance of the strengthening of the masonry walls with concrete columns.

The spatial conformations of masonry structures should follow some important rules according to the seismic standards, for a better spatial configuration and for effectiveness in transmitting the vertical and horizontal loads to the foundations. The strengthening of the masonry walls is the major priority nowadays, on old or new buildings, due to their high vulnerability to earthquakes (Bahman, 2008).

4. ACKNOWLEDGEMENTS

This work was partially supported by the strategic grant POSDRU/159/1.5/S/137070 (2014) of the Ministry of National Education, Romania, co-financed by the European Social Fund – Investing in People, within the Sectorial Operational Programme Human Resources Development 2007-2013.

5. REFERENCES

Durham, A.S., 2004. Influence of confinement on the cyclic behaviour of reinforced clay brick masonry walls. TMS Journal.

Tena-Colunga, A, Juarez-Angeles, A., Salin-Vallejo, V.H., 2009. Cyclic behaviour of combined and confined masonry walls. Engineering Structures 31.

Ismail, N., Petersen, R.B., Masia, M.J., 2011. Diagonal shear behaviour of unreinforced masonry wallettes strengthened using twisted steel bars. Construction and Building Materials.

Plesu, R., Taranu, G., Covatariu, D., Gradinariu, I.D., 2011. Buletinul Institutului Politehnic din Iasi. pg. 165-176. Iasi. Romania.

Porto, F., Mosele, F., Modena, C., 2010. Experimental testing of tall reinforced masonry walls under out-of-plane actions. Construction and Building Materials 24.

Zhou, D., Lei, Z., Wang, J., 2013. In-plane behaviour of seismically damaged masonry walls repaired with external BFRP. Composite Structures 102, pg. 9-19.

Dogariu, A., 2009. Seismic retrofitting techniques based on metallic material of RC and/or masonry buildings. PhD Thesis, Politehnica University Timisoara. Romania

Petersen, R.B., 2009. In-plane shear behaviour of unreinforced masonry panels' strengthened with fibre reinforced polymer strips. PhD Thesis, The University New Castle. Australia.

Secula, S., 2003. Contributii la alcatuirea si calculul structurilor cu diafragme din zidarie. (Contributions for the composition and calculation of masonry panels). PhD Thesis. Politehnica Univeristy Timisoara.

Bahman, G., Masoud, S., Abbas, A.T., 2008. In-plane lateral response of brick masonry walls retrofitted with reinforced concrete layer. The 14th World Conference on Earthquake Engineering. Beijing, China.

Laurenco, P.B., 1998. Experimental and numerical issues in the modelling of mechanical behaviour of masonry. Structural Analysis of Historical Constructions II.

Magenes, G., Calvi, G.M., 1992. Cyclic behaviour of brick masonry walls. Earthquake Engineering, Tenth World Conference. Rotterdam, pp. 3517-3522.

Tumiala, G., Morbin, A., Nanni, A., Modena, C., 2001. Shear strengthening of masonry walls with FRP composites. Composites 2001 Convention and Trade Show. Composites Fabrication Association. Tampa, FL.

Partene, E., 2014. Cyclic in-plane experimental tests for evaluation of shear capacity of brick masonry walls. 9th International Masonry Conference. Guimaraes. Portugal.

Partene, E. 2013. Numerical analysis for evaluation of shear capacity of brick masonry walls. Vienna Congress on Recent Advances in Eartquake Engineering and Structural Dynamics. Vienna, Austria.