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Research Article

Finite element analysis of masonry walls reinforced with expanded steel plates

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ABSTRACT

Existing commercial software (such as ANSYS or other similar software) can be used to efficiently model complicated masonry walls, according to the results of the study. The numerical simulations and calculations used in this study helped to improve our understanding of the structural response of unreinforced and TRM-strengthened masonry walls subjected to diagonal compressive. Masonry constructions are made up of masonry units (brick, stone, marble, etc.) that are joined together using mortar. The models are implemented in ANSYS software to simulate the structural behavior of a tested wall in literature. Brick and mortar are modeled separately in the micro model. The results obtained in the micro modeling and are inconsistent with the experimental study in the literature. The model is implemented in ANSYS and then used to simulate the structural behavior of a group of walls previously tested in a laboratory. The results obtained with the proposed model are in good accord with those obtained in laboratory tests for the five walls considered.

Keywords Finite element analysis, Masonry units, Micro modeling

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1. Introduction

Masonry structures are built by bonding materials such as natural stone, brick, and aerated concrete together with mortar. Masonry structures have existed for many years and continue to do so. There are many important historical masonry structures such as palaces, bridges, and mosques, which are considered cultural heritage in our country, which has hosted many civilizations in the world. Important historical buildings like this one Due to the uncertainty of strength, unknown earthquake behavior, natural disasters, human factors, ground and environmental conditions, physical and chemical effects, historical textures are in danger of being damaged or even destroyed [1]. In addition to the important historical masonry structures in our country, there are also many masonry structures built in violation of engineering rules. When the structural systems of the buildings are examined according to the 2000 census of the State Institute of Statistics (DIE), more than 50% of them appear as masonry structures [2]. There are many experimental and numerical studies about understanding the structural behavior of masonry structures and strengthening existing masonry structures. In this study, micro-modeling strategies on solid unreinforced masonry and reinforced masonry walls were numerically analyzed. For this, masonry walls reinforced with expanded steel plates as a strengthening technique were examined. For the modeling, the results of reinforced and unreinforced masonry walls experimentally examined by Ahmadzai [3] in the literature were taken into account. In Ahmadzai's study, the reinforcement technique of masonry (block) brick walls with expanded steel plate was used, and the effect of using expanded steel plates of different thicknesses on the strength and behavior of block brick walls was investigated. The model in Ahmadzain's work is implemented in ANSYS software to simulate the structural behavior of walls. In the micro model, brick and mortar are modeled separately.

2. Modeling of masonry walls

Computer technology, which has improved in recent years, and the construction and construction elements finite element method modeling has started to be widely used. The finite element can be divided into simpler subunits of complex building or building elements, by determining the behavior of the unit and resolving the system behavior approaches [4]. When using this method, the geometry is divided into simple subunits called finite elements, then each subunit behavior can be determined and system behavior can be understood. The method in question accuracy depends on the accuracy of the data used and the resulting should be predicted [5]. SAP2000, ANSYS for finite element modeling. Many package programs are available, such as ABAQUS. Nonlinear masonry walls advanced plasticity and finite element to properly model the behavior of analysis information is required [6]. So look for a strong user in this study, ANSYS package program with a face is preferred. In the program in question, ready-made element modules that may be needed during modeling and analysis will make it easier to use [7].

2.1. Modeling techniques used in masonry walls

Techniques used to model non-linear analysis of stacking structures homogeneous and heterogeneously collected under two sub-headings. A heterogeneous micro-modeling, which is a modeling technique that is simplified in itself micro, and it is divided into detailed micro modeling. The macro modeling technique is known as homogeneous modeling. Diagram of modeling techniques as shown in Figure 1. In this study, we used mico-modeling technique [8].

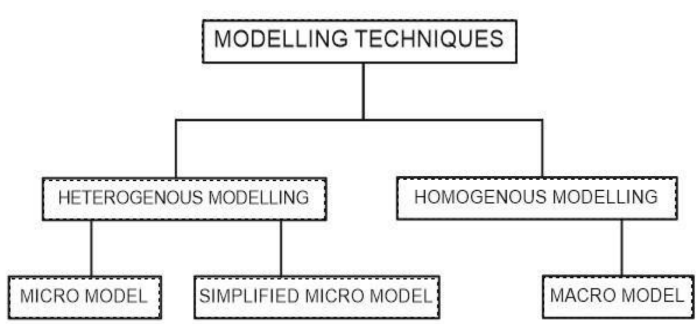


Figure 1 Modeling techniques for masonry walls [8, 9].

2.2. Micro modeling

In micro-technique, masonry units (brick, stone, etc.) and the mortar are modeled separately. Interfaces in the joining areas of these elements can also be included in the model. The micro modeling is shown in Figure 2. Although modeling of structures with micro modeling technique is a detailed process, the local behavior of the structures can be investigated with this technique.

3. Finite element models of masonry walls

The model based on the micro-scale approach was created in ANSYS 2021. The mesh of the model was done in the following three main stages. First, the half brick was created with interface elements to represent the brick crack and the brick joint, and then the basic brick was duplicated to create the two-brick model with all the interface elements required for simulation. Lastly, the two-brick model was replicated in the horizontal and vertical direction to achieve the required dimensions of 1x1m. SOLID 65 finite elements in the ANSYS software were used for the finite element analysis. This element has 8 node points and each node point has 3 displacement degrees of freedom in x, y, and z directions. It can show collapse mechanisms both tensile and compression. Brittle materials can be modeled such as rock, stone, brick concrete, etc. This element is suitable for modeling of nonlinear behavior of structures and cracks can be determined in the structure. The structure of the SOLID 65 elements is shown in Figure 3 [11].

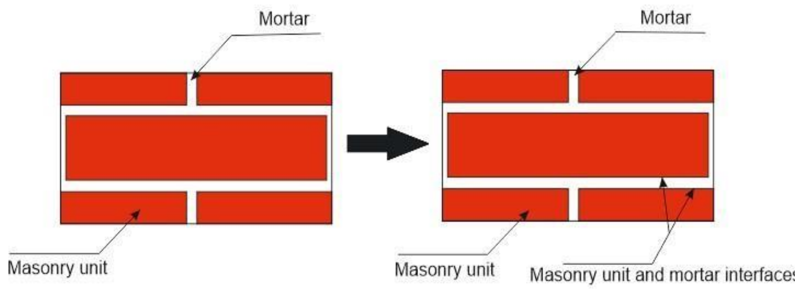


Figure 2 Micro modeling procedure [8-10].

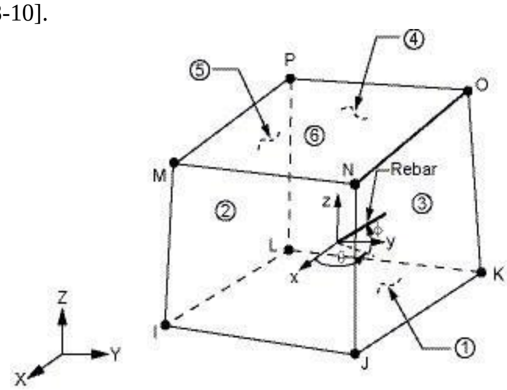


Figure 3 SOLID 65 element.

Material parameters used in the models are shown in Table 1 and the wire steels properties as shown in Table 2 [3]. Brick and mortar material parameters were implemented to the micro finite element model.

Table 1 Material properties [3].

Material	**E(kn_2)cm**	υ
Brick	200	0.15
Cement mortar	70	0.2
Wire steel	3266	0.25

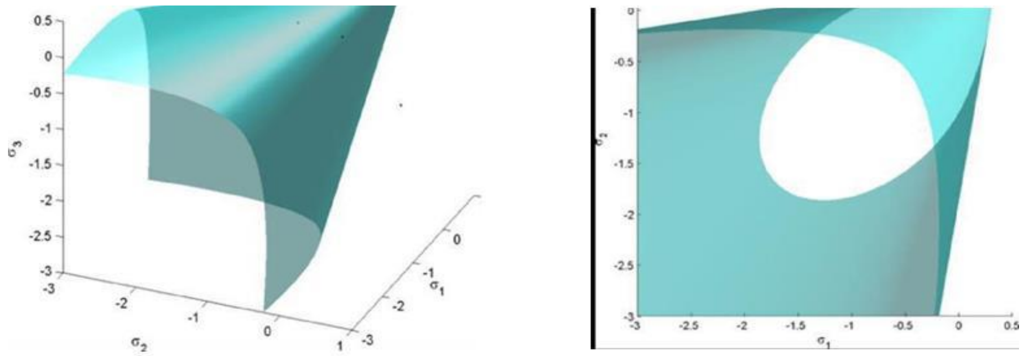
Table 2 Wire steels properties [3].

Walls	**Name**	**Thickness(mm)**	**Bolt space (cm)**
Wall1	Reference	-	-
Wall2	MBW 3-400	3	40
Wall3	MBW 1.5-150	1.5	15
Wall4	MBW 2-150	2	15
Wall5	MBW 3-150	3	15

In the numerical analysis, the Willam-Warnke fracture hypothesis is used for the nonlinear behavior of the masonry wall [8, 9]. The three-dimensional fracture surface and two-dimensional fracture surface for the Willam-Warnke hypothesis are shown in Figure 4. Willam-Warnke's hypothesis is a suitable hypothesis for materials having different compressive strength and tensile strength such as masonry materials. Masonry materials usually have high compression strength and low tensile strength.

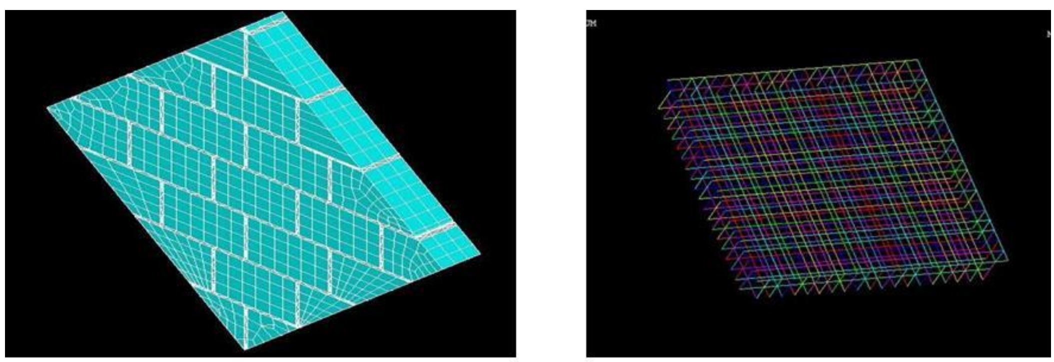
3.1. Micro finite element model

The geometry of the model and finite element mesh was produced with the micro modeling technique. In this technique, bricks and mortar are modeled separately. For meshing, we used sweep mesh to bricks and free mesh for cement mortar and steels. Figure 5 indicates the geometry and the finite element mesh of the micro model.



(a) (b)

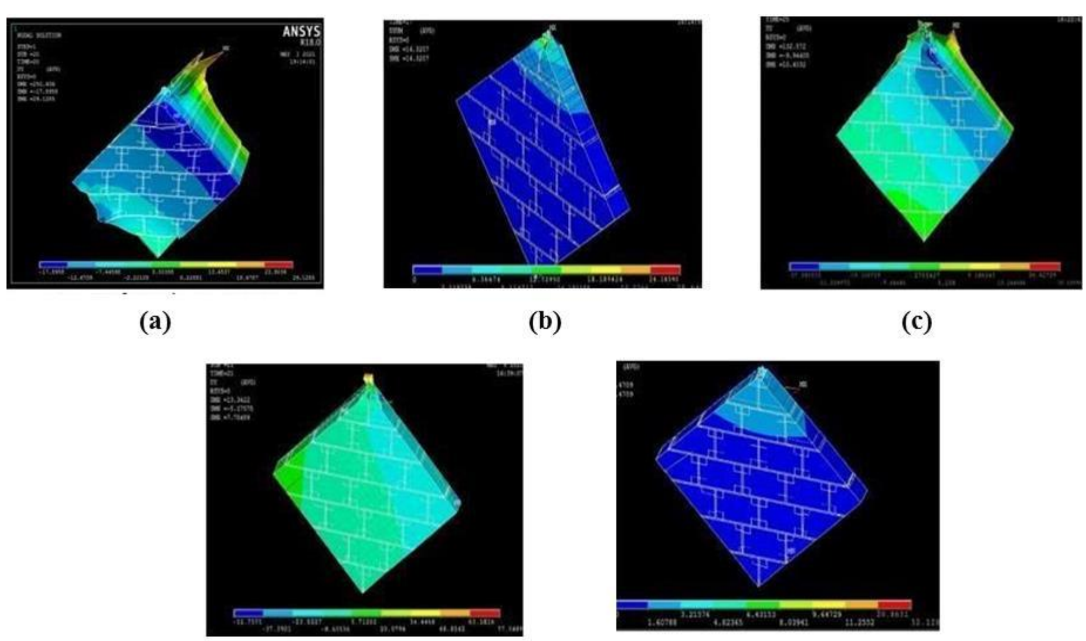
Figure 4 Willam-Warnke fracture surfaces (a) Three dimensional space and (b) Two dimensional plane [10, 11].



(a) (b)

Figure 5 (a) Wall1 after meshing and (b) Steels mesh.

Deformation of walls under ultimate diagonal loading for reference and strengthened walls with different steel mesh thickness are shown in Figure 6.



(a) (b) (c)

(d) (e)

Figure 6 (a) Deformation reference wall, (b) Deformation of MBW 3.0-400, (c) Deformation of MBW 1.5-150, (d) Deformation of MBW 2.0-150 and (e) Deformation of MBW 3-150.

4. Results and discussion

In this study, unreinforced masonry wall strengthened masonry walls were modeled and analyzed using the finite element method. The proposed model was implemented and applied to the five walls presented in the literature. The parameters related to geometry are taken from the information given previously as well as some other information related to the properties of the materials. The compare results of micro modeling and experimental walls are shown in Table 3.

Table 3 Main results of the numerical and experimental walls.

Walls	Maximum load (kN) in ANSYS	Deformation (mm) in ANSYS	Maximum load (kN) in experimental	Deformation (mm) in experimental
Wall reference	96	29.1	99.85	25.9
Wall MBW 3.0-400	150	28.6	147.02	25.3
Wall MBW 1.5-150	157	77.5	154.65	65.40
Wall MBW 2.0-150	159	30.1	161	34
Wall MBW 3-150	155	32.1	160.5	36.75

4.1. Experimental vs numerical comparisons

In this section, a comparison between experimental and numerical results is discussed. The ANSYS modeling was compared with the test results and the behavior had been observed. The numerical load versus displacement and compared with the experimental results were shown in Figure 7. A review of the numerical data leads to recognizing that if the micro-modeling strategy was applied, the overall response of the masonry panels can be well predicted in terms of the collapse load and the deformation values as well as sufficiently accurate failure mechanisms can be predicted. At the end of the results, it may be concluded that the strengthening technique provided the best results in terms of both load and deformation, making the panel more resistant against diagonal compression loads.

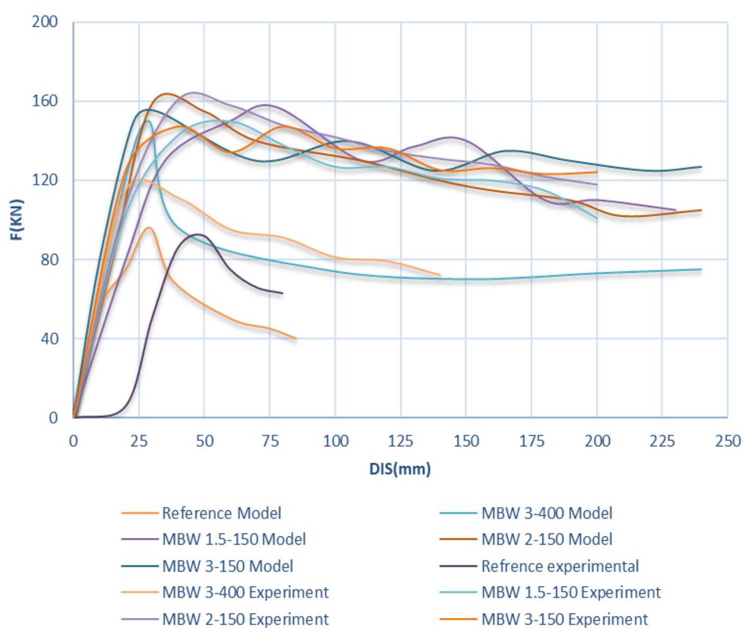


Figure 7 Comparative load-displacement curves of all model and experimental wall samples.

5. Conclusion

The study presented has shown that existing commercial software (such as ANSYS or other similar software) can be used to effectively model complex use of masonry walls. The numerical simulations calculations carried out in the present research have contributed to enhancing the understanding of the structural response of the unreinforced and strengthened masonry walls subjected to diagonal compressive loading conditions and the results of numerical micro modeling masonry brick walls under diagonal loading show us goo agreement between ANSYS results with experimental results from the results of numerical simulations work the following conclusions can be drawn. Numerical analysis showed that the technique provided more satisfactory results in terms of higher resistance and more ductility levels. The development of a unique finite element modeling strategy, which was designed to explicitly model the reinforcement mechanism of the reinforcement. In depth analysis on failure modes and reinforcing mechanisms of strengthened masonry wall panels using the combination of experimental results and advanced finite element modeling. From this study, it is concluded that within a short time complex structure analysis can be performed which takes a longer time experimentally. Different material properties can be easily assigned to the model and their behavior change can be found out. In addition, the crack pattern of the masonry structure can be identified using this numerical study. Finally, the numerical model showed good agreement with the results of laboratory tests.

Conflict of Interest

The authors declare that there is no conflict of interest.

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