

Linear Elastic Analyses of Masonry Walls

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Abstract

Masonry structures are commonly used in many countries. Load bearing masonry walls are the most important structural element in the masonry structures. In this study, a computer program was written in MATLAB for linear elastic analyses of masonry walls. In addition, a mesh program which meshes the wall as two dimensional model was written in MATLAB. These models were constituted with macro modelling approach. Three different load cases were applied to two dimensional masonry model with opening. The obtained results from the linear elastic analysis were compared with ANSYS software results.

Keywords: Masonry walls, Linear elastic behaviour, Finite element method

Yığma Duvarların Lineer Elastik Analizi

Özet

Yığma yapılar birçok ülkede yaygın olarak kullanılır. Bu yapılardaki en önemli yapı elemanı taşıyıcı duvarlardır. Bu çalışmada, yığma duvarların lineer elastik analizi için MATLAB dilinde bir bilgisayar programı yazılmıştır. Ayrıca yine MATLAB dilinde duvarın iki boyutlu olarak sonlu eleman modelini oluşturabilen bir program yazıldı. Yığma duvar modelleri makro modelleme yaklaşımıyla modellendi. Pencere açıklığına sahip duvar modellerine üç farklı yükleme uygulanarak elde edilen lineer elastik analiz sonuçları ANSYS program sonuçları ile karşılaştırıldı.

Anahtar Kelimeler: Yığma duvar, Lineer elastik davranış, Sonlu eleman metodu

1. Introduction

Masonry is the oldest building material that still finds wide use in today's building industries [1]. Masonry structures are the construction systems where walls, comprised of mortar and masonry units such as briquette, brick, stone and adobe, are used as load bearing system. Undoubtedly, the most important structural element for masonry structures is the load bearing walls. These structures are commonly used in many countries all over the world. The most important characteristic of masonry construction is its simplicity. Laying pieces of stone, bricks or blocks on top of each other, either with or without cohesion via mortar, is a simple, though adequate, technique that has been successfully used ever since remote ages [2]. Half of the existing building stock is consist of masonry structures in Turkey [3]. The vast majority of these structures are located in the rural areas and neighborhoods

around the city. Masonry structures prefer over other structural systems because the relevant materials can be easily obtained and their construction and workmanship are easier. For this reason, the ratio of masonry structures increase to 82% in rural regions [4]. Masonry structures can be divided into three groups as confined, unreinforced and reinforced masonry structures. These structures are commonly constructed as to be unreinforced masonry in Turkey. These structures are constructed with traditional techniques using locally available materials. Nearly no engineering services are used in these buildings.

2. Modelling of Masonry

Masonry is a material which exhibits distinct directional properties due to the mortar joints which act as planes of weakness. In general, the approach towards the numerical representation of masonry can focus on the

micro-modeling of the individual components, unit (brick, block, etc.) and mortar, or the macro-modeling of masonry as a composite [5]. Depending on the level of accuracy and the simplicity desired, it is possible to use one of the modeling strategies. Three different strategies which called detailed micro modeling, simplified micro modeling and macro modeling are used for modeling the masonry structure. One modeling strategy cannot be preferred over the other because different application fields exist for micro and macro models. In the detailed micro modelling, the material specifications of

the masonry units and the mortar, i.e., the modulus of elasticity, density and Poisson ratio are evaluated separately. The masonry units are widened by as much as half of the mortar layer in the simplified micro-modelling. Thus, the mortar layer is neglected, and the masonry units are separated from each other with interface lines. Macro-modelling is an equivalent material model that assumes the construction elements to be a composite without any exception among stone, brick and mortar. These modeling strategies are given in Figure 1.

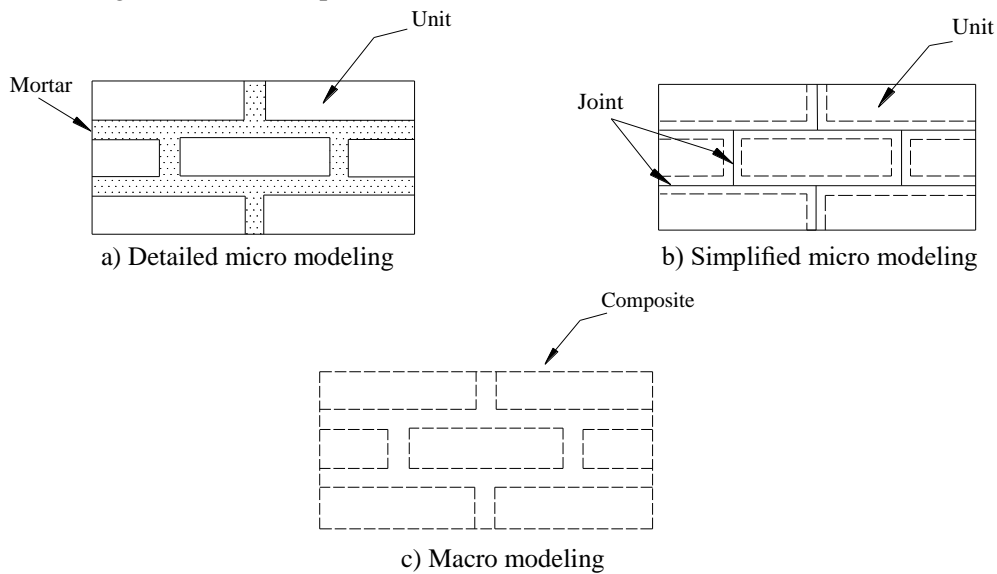
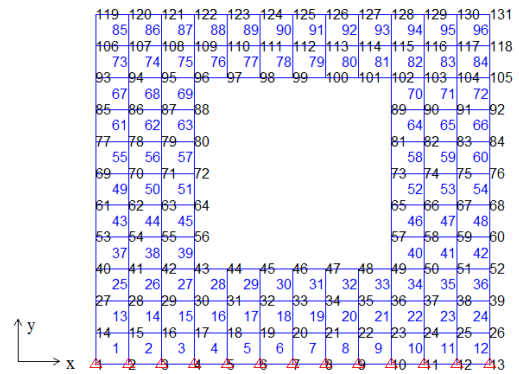


Figure 1. Modeling strategies of masonry structures [1]

3. Linear Elastic Analyses

In this study, linear elastic analyses of a masonry wall was performed. For this purpose, a program that can perform linear analyses of masonry walls was written in MATLAB. The program was named as masonry-lin. Also, a mesh program was written in MATLAB that can draw the wall with and without opening and prepare the necessary information as input file for the masonry-lin [6]. The mesh program model the masonry wall as two dimensional by means of the macro modelling approach. Node coordinates, element and node numbers, element connectivity, restrained nodes and material properties are prepared with the mesh program as the input file for the masonry-lin. Finite element mesh of the wall with and without opening created by the mesh program was presented in Figure 2. In this figure, black and blue numbers

on the wall show node points and element numbers, respectively. The masonry-lin. uses this input file and starts the analysis. It calculates displacement, stress and strain values of the node points.



a) with opening

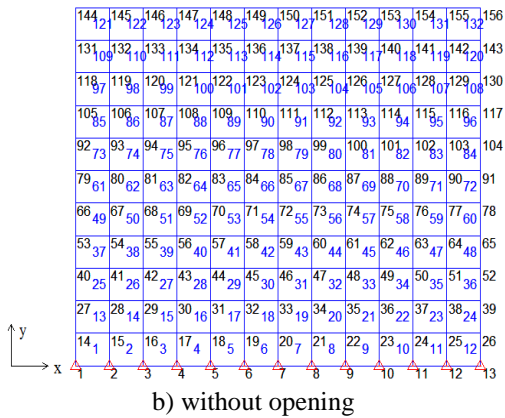


Figure 2. Finite element mesh of the masonry wall

In finite element implementation, finite element model of the masonry wall is constructed using quadrilateral elements, with four nodal points and two degrees of freedom on each nodal point. Element stiffness matrixes were found using 2x2 Gauss integration rule. The flow diagram of the masonry-lin. is presented in Fig. 3.

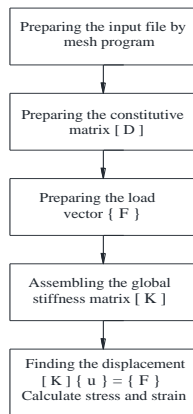


Figure 3. Flow diagram of the masonry-lin

Three different load cases were applied to two dimensional masonry model with opening. The base nodes of the wall were fixed in x and y directions at all load cases. For first and second load case, single load was applied at horizontal and vertical direction, respectively. For third load case, these two single loads were applied together to the masonry wall model.

Value of the single load was considered as 50 kN. The modulus of elasticity, mass per volume and Poisson's ratio for the masonry unit was considered as 5×10^3 Mpa, 1.2 t/m^3 , and 0.20,

respectively. The dimension of the masonry wall used in the analysis was shown in Figure 4.

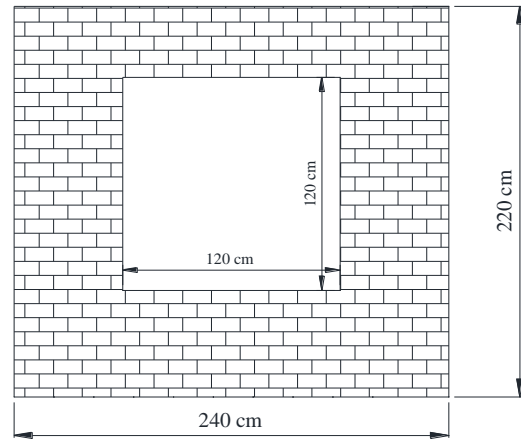
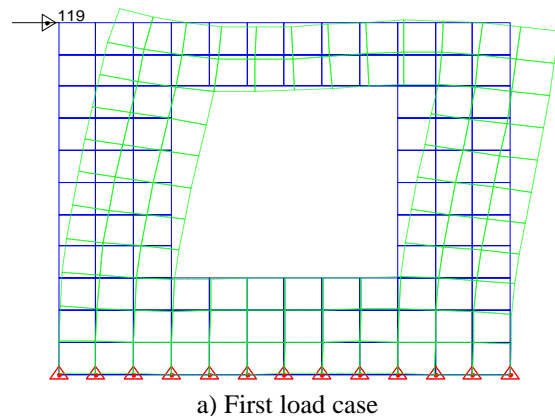


Figure 4. Dimension of the masonry wall

For first load case, the single load was applied in the x direction at nodal point 119. For second load case, the single load was acted in the negative y direction at nodal point 125. For third load case, these two single loads were applied at the same nodes and at the same directions (Fig. 5).

Deformed and undeformed shape of the masonry wall for three different load cases obtained the masonry-lin. is shown in Figure 5. In this figure, solid blue and dashed green lines show the undeformed and deformed shape of the masonry wall.



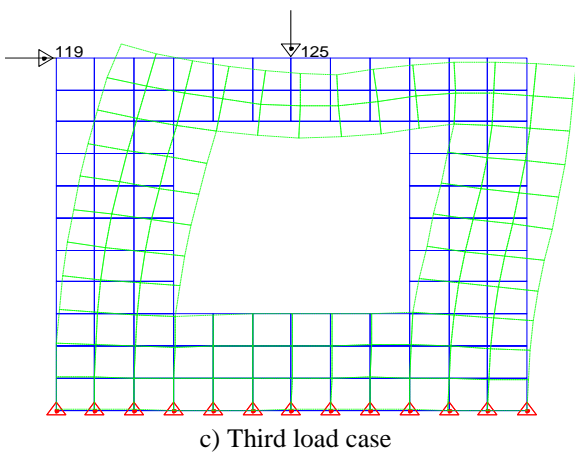
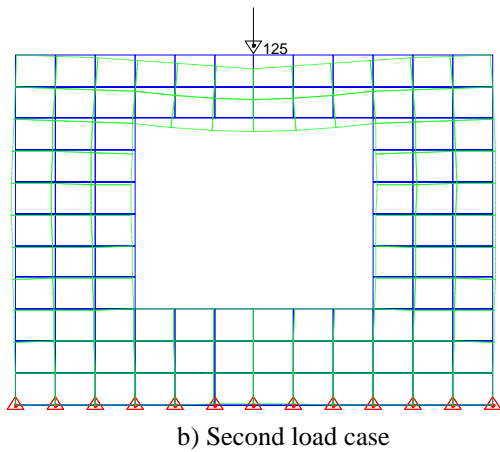


Figure 5. Undeformed and deformed shape of the masonry wall with different load cases

Two node points was selected on the masonry wall for comparing displacement and stress values acquiring from masonry-lin and ANSYS software. These points is given in Figure 6. Displacement values of the node point 131 obtained from the masonry-lin. and ANSYS software under first, second and third load cases is presented in Table 1.

Also, the masonry-lin. can calculate the maximum and minimum principal stress of the node points. Maximum and minimum principal stress values of the node point 117 under first, second and third load cases is presented in Table 2. Same displacement and stress values were obtained according to the analysis results.

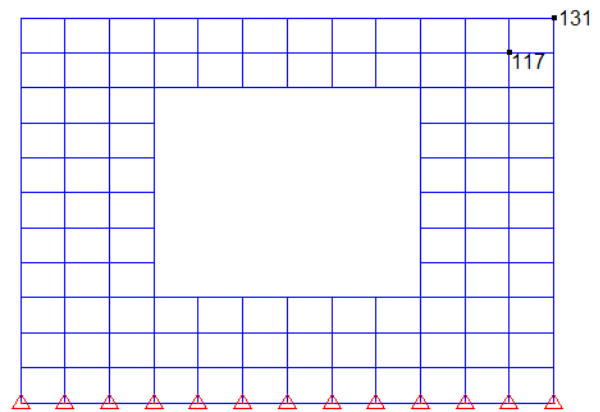


Figure 6. Selected node points

Table 1. Displacement values of the node point 131

Load cases	Masonry-lin.		ANSYS	
	x (mm) direction	y (mm) direction	x (mm) direction	y (mm) direction
First load case	1.285	-0.277	1.285	-0.277
Second load case	-0.0542	-0.0104	-0.0542	-0.282
Third load case	1.233	-0.282	1.233	-0.282

Table 2. Maximum and minimum principal stress of the node point 117

Load cases	Masonry-lin.		ANSYS	
	max. principal stress (kPa)	min. principal stress (kPa)	max. principal stress (kPa)	min. principal stress (kPa)
First load case	144.24	-141.06	144.24	-141.06
Second load case	84.45	-94.17	84.45	-94.17
Third load case	227.60	-232.95	227.60	-232.95

4. Conclusion

In this study, a computer program was written in MATLAB to perform linear elastic analyses of masonry walls. Furthermore, a mesh program which meshes the wall as two dimensional was written in MATLAB. These

masonry walls were constituted with macro modelling approach. Three different load cases were applied to these walls. Accuracy of the results obtained from the masonry-lin. were compared with ANSYS software results.

6. References

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