

Performance of Brick Wall Buildings Subjected to Lateral Loads

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ABSTRACT: This paper deals with performance of brick wall buildings to lateral loads. The analysis is carried out by using nonlinear static pushover method. In this study, the modeling and pushover analysis is conducted by using the finite element program ANSYS (V.11). The nonlinearity behavior of the bearing wall is considered by proper constitutive assumptions. In this paper, model of one story house is considered to highlight the performance of brick walls subjected to lateral loads. From the investigation, it is found that the ultimate load capacity of the considered building model have greater values when the lateral load applied parallel to the longitudinal direction of the house models than those in the other direction. This demonstrates that the higher contribution of in-plane walls than out-of-plane walls in resisting lateral loads.

KEYWORDS: Brick walls, finite element modeling, nonlinear analysis, pushover method..

I. INTRODUCTION

Brick wall buildings are the oldest building material that still used in for building constructions around the world. The main function of walls is to carry gravity loads including self weight of the building and imposed live and dead loads. However, in regions that prone to earthquakes action, buildings will subject to lateral loads. This paper investigates the performance of brick wall building to lateral loads. In the analysis, the building is modeled using finite element simulation approach. Specific assumptions of the material properties and the nonlinear behavior of the wall were considered. Pushover analyses were performed to evaluate building capacity under lateral forces. Capacity curves of the building model were determined by pushover analyses conducted in two principal directions. A certain number of methods have been utilized for modeling brick wall buildings^[1].

Most bearing walls are a composite material consisting of brick units and mortar joints. In order to reflect the complex nature of the wall, a complete model should accommodate discrete brick units, mortar joints and the unit-mortar interface whose mechanical properties are different. Wall modeling involves different modeling approaches with different complexity and accuracy that include detailed micro-modeling, simplified micro modeling, macro modeling and equivalent frame modeling. Detailed micro-modeling in which the brick and mortar joints are modeled as continuum elements and interface between the brick and mortar is modeled by an interface element as shown in Fig.(1-b)^[1]. Both the continuum elements and interface elements may be defined by nonlinear stress-strain relations. Separate constitutive models are used to define the bricks, the mortar joint and the interface between the mortar and bricks. In the simplified micro-modeling bricks are modeled by continuum elements, but the mortar joint and its interface with bricks is modeled together in an interface element^[1] as shown in Fig.(1-c). In the modeling of large structural elements, a relation might be defined between average wall stresses and average wall strains since neglecting heterogeneous nature does not have a great effect on global behaviour. Instead of complex modeling, homogenization of brick units and mortar joints is utilized to present finite element macro model of wall as shown in Fig.(1-d). Compared to micro models, less amounts of material parameters are required which means less amounts of experimental work is adequate for macro model^[2]. Therefore, macromodeling is more practical approach due to the reduced required modeling and analysis time and memory in which it is adopted in this study. In this study, walls are represented by macro modeling approach that modeling is conducted using the general finite element program ANSYS (V. 11.0)^[3].

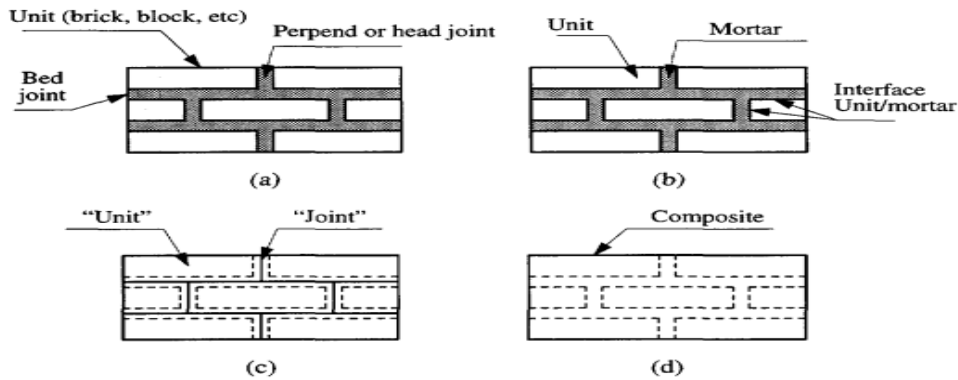


Fig. 1. Modeling strategies for masonry structures^[1]: (a) masonry sample; (b) detailed micro-modeling; (c) simplified micro-modeling; and (d) macro-modeling.

Equivalent frame method is a simple way to conduct nonlinear analyses of bearing wall structures. The non-linear behavior of wall panels and piers (equivalent frame model) could be represented by 2-nodes macro-elements. The structure is modeled as an assemblage of vertical (pier) and horizontal (spandrel) elements. Piers and spandrels were connected by rigid offsets and each element is modeled by proper constitutive relations^[2]. It is clear that this approach presented strong simplifications that might affect the accuracy of the results.

II. WALL MODELLING

The three-dimensional (3D) brick (SOILD 65) element provided by ANSYS (V.11.0)^[3], is used to represent walls in the models. The element is defined by eight nodes having three translational degrees of freedom at each node. This element is capable of cracking in tension and crushing in compression. The most important aspect of this element is the treatment of nonlinear material properties^[3].

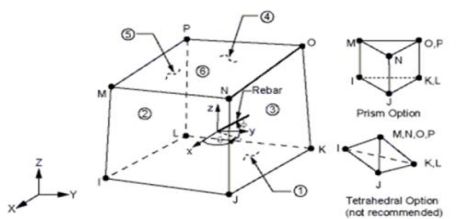


Fig. 2. SOILD 65 Element^[3].

III. NONLINEAR MATERIAL PROPERTIES

The equivalent wall prism compressive strength is given by^[4]:
 $f_e' = 0.63 \cdot f_b^{0.49} \cdot f_m^{0.32} \dots \dots (1)$

Where:

f_e' : compressive strength of a wall prism are in (Mpa) .

f_b : compressive strength of brick are in (Mpa).

f_m : compressive strength of mortar are in (Mpa).

The elastic modulus of masonry (E_m) was calculated from the compressive strength of a wall prism (f_e') according to eqs. (1)^[4].

$$E_m = 550 \cdot f_e' \dots \dots (2)$$

Simplified stress-strain curve for equivalent wall material shown in Figure (3) is adopted. The simplified stress – strain curve for equivalent wall material is construction from five points connected by straight lines. The curve starts at the origin point, point one is at strain equal 0.001 and calculated from equation(3), point four is at f_m' and ϵ_m' , the other points are calculated from equation (4) ^[5]:

$$\epsilon = \frac{f}{E_m} \dots(3)$$

$$f = f'e'(2 * (\frac{\epsilon}{\epsilon_0}) + (\frac{\epsilon}{\epsilon_0})^2) \dots(4)$$

ϵ_0 : strain at the ultimate stress f_m'

ϵ : strain in (Mpa).

f :stress at any strain ,in (Mpa).

$f'e'$: compressive stress of wall prism in (Mpa).

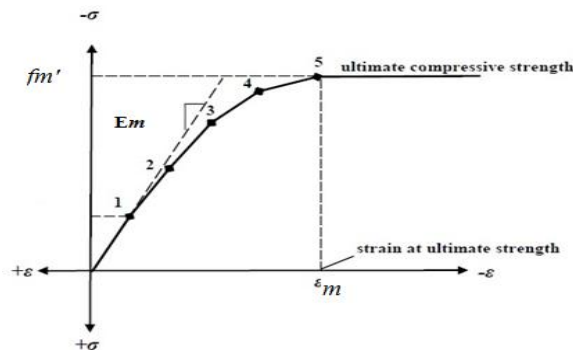


Fig. 3. The simplified compressive stress-strain curve for equivalent wall material.

IV. NON-LINEAR PUSHOVER ANALYSIS

Non-linear pushover analysis is used to determine the lateral capacity of the buildings. In pushover analysis, the load is applied in steps until the structure becomes unstable due to unconservancy^[6]. The roof displacement is plotted with resultant of applied load to obtain the global capacity curve; i.e., Pushover curves (Figure 4).

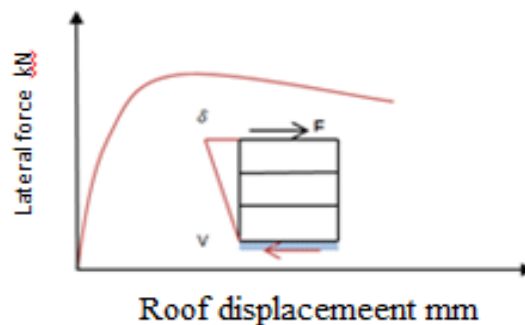


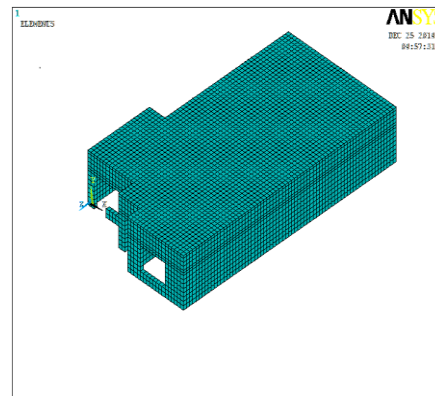
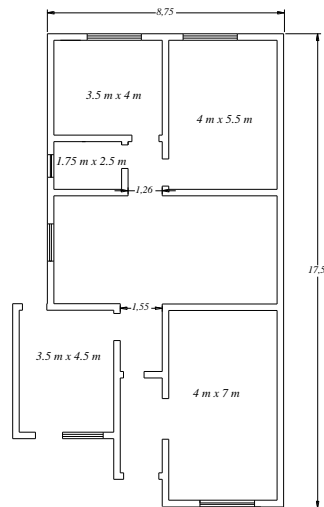
Fig. 4. Typical pushover curve of a structure.

V. BEARING WALL BUILDING MODEL

The adopted model represents one story house. In this case, brick walls are built from clay brick units and cement mortar. The model is subjected to vertical load (dead load & live load) according to ASCE 7-10^[7]. In this study 2kN/m² is considered for live load 7.6kN/m² for dead load including self weight of slabs. Figure (5-a) illustrates the typical plan of the house model. The dimensions of the room are 6m length, 4m width and 3m height. The one story building model plan layout and dimensions are shown in Figure (5-a). The dimensions of the doors are 1m length, 2.1m height and the dimensions of the windows are 1.5m length, 1.5m height. A continuous reinforced concrete lintel is placed above the openings. The lintel dimensions are 0.24 m width, 0.3m depth. The properties of the materials are illustrated in Table (1). The finite element modeling of the adopted of a one story house is conducted in this study as shown in Figure (5-b).

Table (1): Material properties

Compressive strength of mortar f_j (MPa)	Compressive strength of clay brick f_b (MPa)	Compressive strength of prism f_c' (MPa)
15.2	13	3.967



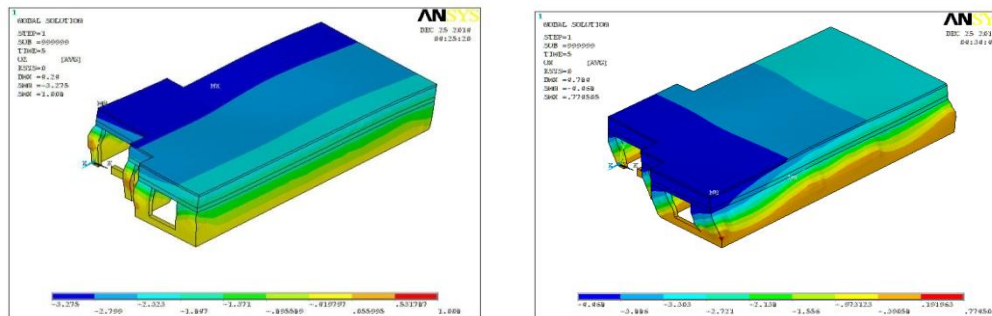
(a) The details and dimension

(b) Finite element idealization

Fig. 5. The details and finite element idealization of the house.

VI. RESULTS AND DISCUSSION

Results of pushover analysis in terms of final deformation pattern are illustrated Figure (6). The capacity curve representing applied load versus lateral displacement of the model are depicted in Figure (7). The analysis results show that the ultimate load capacity of the considered building model have greater values when the lateral load applied parallel to the longitudinal direction of the house model than that in the lateral direction. It can be noted from the plan layout that along the lateral direction there are more number of openings including doors and windows than in the longitudinal direction. Also, the length of the walls in the longitudinal direction is greater than those in the lateral direction. Consequently, it is demonstrated that the higher contribution of in-plane walls effect than out of-plane walls effect in resisting lateral loads.



(a) Transverse (b) Longitudinal

Fig.6. Deformation shapes of the house model.

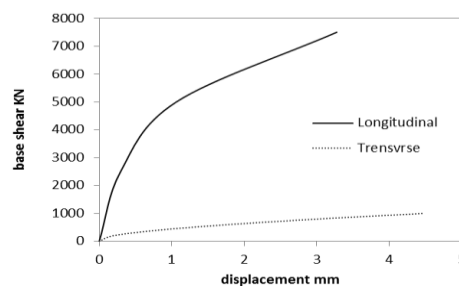


Fig. 7. Capacity curve of the house model.

VII. CONCLUSION

This study evaluates lateral load capacity of brick wall buildings considering nonlinear behavior of the adopted model. One story house model is selected to determine capacity curves representing applied load versus top lateral displacement of the investigated building. The capacity curves are determined by pushover analyses conducted in two principal directions. The numerical analyses are carried out by using the general purpose finite element program ANSYS Release 11.0 in which the adopted concrete element **SOLID 65** utilized for macro modeling in this study have been successfully predict the nonlinear behavior of the bearing wall buildings subjected to lateral loads. From the investigation, it is found that the ultimate load capacity of the considered building model have greater values when the lateral load applied parallel to the longitudinal direction of the house model than that in the lateral direction in which there are more number of openings including doors and windows in the lateral direction than in the longitudinal direction. Also, the length of the walls in the longitudinal direction is greater than those in the lateral direction. Consequently, it is demonstrated that the higher contribution of in-plane walls effect than out of-plane walls effect in resisting lateral loads.

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