Developing Interaction Curve for the Seismic Design of Masonry Buildings

Rasheeda. A A[1], Nisha Varghese[2], Sivan.P.Parameswaran[3]

Abstract— Masonry constructions are the most common type used for all housing purposes. They are classified as unreinforced, reinforced and confined masonry structures. The buildings made of brick and stone are superior with respect to its durability, heat resistance and fire resistance. The masonry structures are most vulnerable to and suffered heavy damages during earthquakes. The analysis is difficult because of its complex nature. This paper focused on buildings with plan area 600 square feet. The irregularities from its symmetry results in different eccentricity values. The difference of center of mass and center of rigidity of each building gives the eccentricity. The buildings with these different eccentricity values are analyzed using the software TREMURI, which is based on the equivalent frame modelling approach. The analysis gives pushover curve. Shear strength values are tabulated from the analysis. The parameter shear strength and eccentricity values are used to plot the interaction curve for each plan.

Index Terms— centre of mass, centre of rigidity, eccentricity, interaction curve, masonry constructions, pushover curve, shear strength

1 INTRODUCTION

MASONRY constructions is the most commonly used construction technique in almost all over the world due to the low material costs,material availability and availability of skilled labors.Masonry is a non-elastic,non-homogeneous and anisotropic which is a composition of bricks and mortar.In unreinfoeced masonry building both load bearing and non load bearing walls are made of brick or other masonry material which is not braced by reinforcing material.Unreinforced masonry buildings were designed to resists both gravity and wind loads and are unable to resist seismic loads.Under vertical loads masonry has high compressive strength but has low tensile strength.Due to its low capacity in tension and shear masonry has poor performance in seismic actions.

For the production of traditionally and industrially made masonry units, a wide variety of natural and artificial raw materials are used. Each masonry component has its own specific mechanical characteristics. When subjected to permanent and temporary actions masonry wall acts as a homogeneous structural material. Depending on the materials composed together in a masonry construction, they are classified as Unreinforced or plain masonry which consists of mortar and masonry units, Confined masonry which consists masonry units, mortar, reinforcing steel and concrete, Reinforced masonry which consists masonry units, mortar, reinforcing steel and concrete infill.

1 M. Tech Student, Structural Engineering, Vidya Academy of Science and Technology, Thrissur, Kerala,Email:786rasheedamujeeb@gmail.com
2 Assistant Professor, Department of Civil Engineering, Vidya Academy of Science and Technology, Thrissur,Kerala,Email:nisha.v@vidyaacademy.ac.in
3 Ph. D, Scholar, Karunya University, Coimbatore, India, Assistant Professor Department of Civil Engineering, Government Engineering College, Thrissur, Kerala,Email:ppsivan@yahoo.com
.

Unreinforced masonry buildings are vulnerable to earthquakes and may cause collapse.Depending on the frequency of earthquakes in a region,seismic actions are actions with low probability.Earthquakes caused by various natural phenomena such as tectonic process,volcanic eruptions,sudden failure of parts of the ground in terrain and by human activities, are ground motions generated by sudden displacements within the earth's crust.The mechanism of earthquake is explained by elastic rebound theory.According to this theory, strain that has accumulated in rock materials along the fault due to relative deformation of tectonic blocks in a long period of time between two earthquakes, has attained the ultimate limit.Forces acting on the building during an earthquake are induced by ground motion and depend on the intensity of the motion.The data needed for structural verification and design can be directly obtained from ground acceleration records.

Seismic analysis is classified as linear static and dynamic analysis and non-linear static and dynamic analysis. A useful tool for determining the ultimate load and deflection capacity of a structure is non-linear static analysis. TREMURI software follows an equivalent frame model approach for the non-linear seismic analysis of masonry buildings.

2 METHODOLOGY

Masonry buildings represent box-type structural system composed of vertical and horizontal structural elements such as walls, floors and roofs. Vertical gravity loads are transferred from the horizontal flexural elements to the vertical compression members. From there loads are finally transferred to the foundation system.

Seismic analysis is classified based on the type of external action and the behavior of the structure as linear static and linear dynamic analysis and non-linear static and nonlinear dynamic analysis. The seismic analysis is of having different degree of accuracy. Nonlinear static analysis or pushover analysis is a useful tool for determining the ultimate load and deflection capacity of a structure. Pushover analysis is a non-

ISSN 2229-5518

linear static analysis for the seismic assessment of masonry structures and is based on an equivalent frame idealization of the structure. Pushover analysis is a practical tool for the evaluation of the seismic response of structures.

TREMURI software follows non-linear static analysis or pushover analysis [18]. TREMURI program is an equivalent frame model for the non-linear seismic analysis of masonry buildings [8]. The equivalent frame model approach allows the analysis of complete 3D buildings with a reasonable computational effort. Equivalent frame model considers the walls as an idealized frame [8]. Focusing on the in-plane response of masonry walls with openings, piers and spandrel elements may be identified as two main structural components. Here piers are the vertical resistant elements which carry vertical and lateral loads and spandrel elements which are those parts between two vertically aligned openings acts as horizontal elements [8]. The main output of the pushover analysis is a force displacement curve. It is a curve of base shear versus the lateral displacement at some point at the roof level which includes all the stages of lateral load per displacement increments.

Masonry structures may be symmetric and unsymmetrical in nature. The analysis of unsymmetrical building is a complex task because of the variation of its eccentricity values. This paper focused on buildings with plan area 600 square feet. The irregularities from its symmetry results in different eccentricity values.

IJSER

2.1 Centre of mass and centre of rigidity

The difference of center of mass(COM) of a building and center of rigidity(COR) of a building gives the eccentricity. Rigidity of walls in X and Y directions and center of gravity (CG) of corresponding walls gives the center of rigidity in that direction.

$$\mathrm{COR} = \frac{\sum_0^n kx}{\sum_0^n k} \quad (1)$$

Where k and x are the rigidity of individual walls and center of gravity respectively. Mass of the building and corresponding center of gravity gives the center of mass of the building.

Here M and x are mass of the walls and floors and corresponding center of gravity respectively.

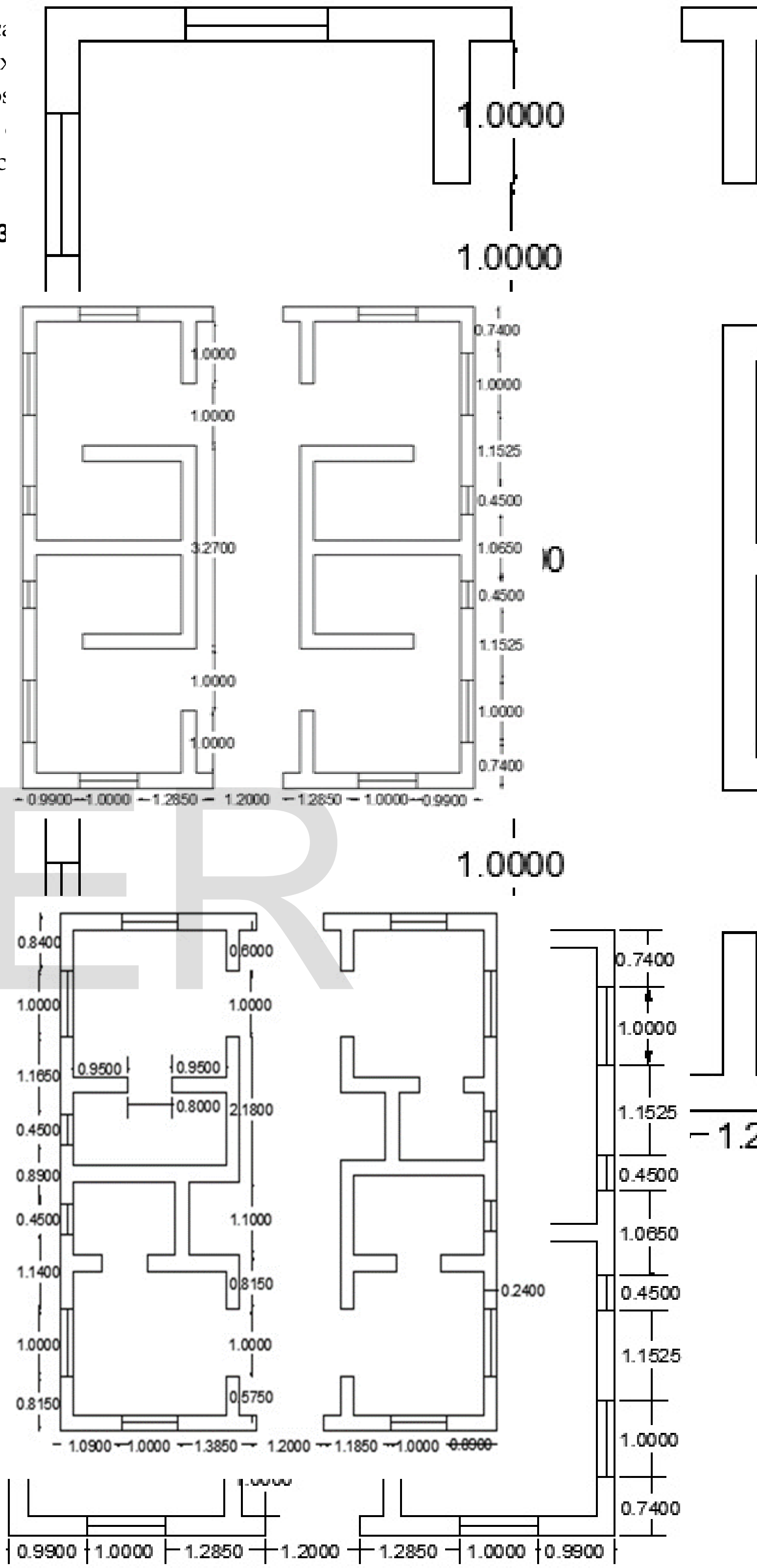
$$\mathrm{COM} = \frac{\sum_0^n Mx}{\sum_0^n M} \quad (2)$$

2.2. METHOD

First calculate eccentricities of symmetrical plan in both X and Y direction. By keeping the plan area, wall density and Y directional eccentricity constant, change the plan to unsymmet-

rica
nex
pos
ty
rec

2.3



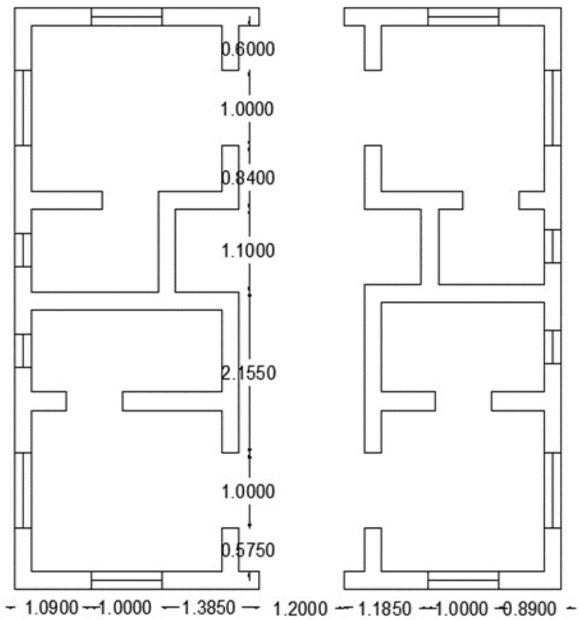


Fig 3.600Sqft unsymmetrical plan Ex=0.11

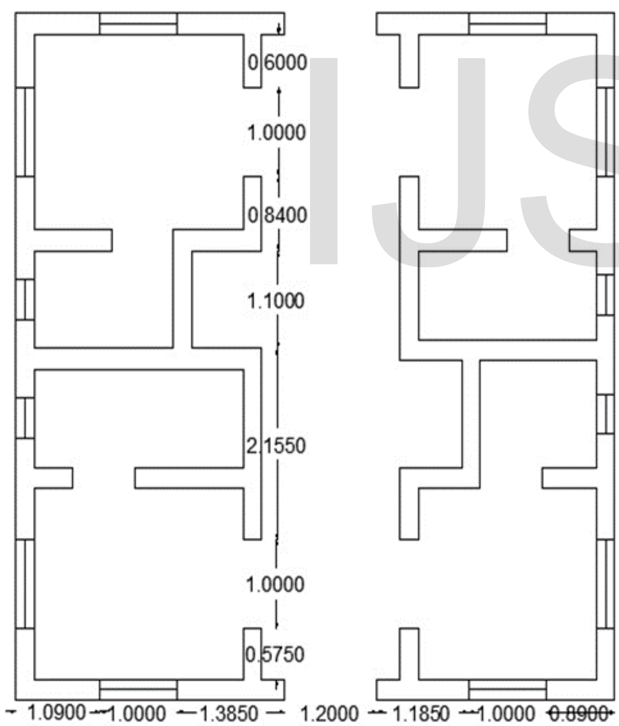


Fig 4.600Sqft Unsymmetrical Plan Ex=0.13

For all this plans the Y directional eccentricity value is constant ie. Ey=0.Likewise by changing the positions of openings change the Y directional eccentricity. By keeping that Y directional eccentricity constant calculate another set of X directional eccentricities. Repeat the above set of calculation to get two more Y directional eccentricities.

2.4 Calculation of Eccentricities

Table shows the calculation of X directional eccentricities by keeping Y directional eccentricity constant. A small change in Y directional eccentricity is neglected.

TABLE 1. Calculation of Ex by keeping Ey=0

COMx	*CORx*	*EX*	*COMy*	*CORy*	*EY*
3.87	3.87	0.00	3.87	3.87	0.00
3.88	3.8	0.10	3.88	3.87	0.01
3.89	3.77	0.11	3.86	3.83	0.02
3.89	3.76	0.13	3.88	3.87	0.01

IJSER

TABLE 2. Calculation of Ex by keeping Ey=0.16

COMx	*CORx*	*EX*	*COMy*	*CORy*	*EY*
3.87	3.87	0.00	3.81	3.65	0.16
3.88	3.73	0.15	3.82	3.97	0.15
3.88	3.72	0.16	3.79	3.62	0.17
3.90	3.73	0.17	3.81	3.97	0.16

TABLE 3. Calculation of Ex by keeping Ey=0.10

COMx	*CORx*	*EX*	*COMy*	*CORy*	*EY*
3.87	3.87	0.00	4.00	3.90	0.10
3.88	3.73	0.15	3.89	3.79	0.10
3.88	3.72	0.16	3.91	3.80	0.11
3.90	3.72	0.18	3.88	3.99	0.11

TABLE 4. Calculation of Ex by keeping Ey=0.13

COMx	*CORx*	*EX*	*COMy*	*CORy*	*EY*

3.87	3.87	0.00	3.91	4.04	0.13
3.88	3.73	0.15	3.91	3.78	0.13
3.88	3.72	0.16	3.88	3.76	0.12
3.90	3.73	0.17	3.76	3.88	0.12

2.5 Analytical Investigation

In this paper the properties of building are fixed for the entire structure. They are described below:

TABLE 5. Building Parameters

DESCRIPTION	*VALUES*
Young's modulus,E	1800 N/mm^2
Shear modulus, G	250 N/mm^2
Load weight,w	19 kN/m^3
Mean compressive strength,fm	2.96 N/mm^2
Mean shear strength,fvm0	0.25 N/mm^2
Shear strength limit,fvlim	2.2 N/mm^2
Characteristic value,fk	2.46 N/mm^2

The modeling is done with the help of TREMURI software.

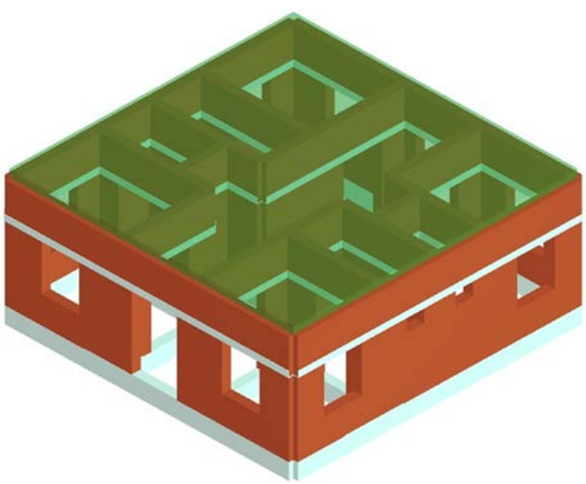


Fig.5 TREMURI model

While completing, the analysis gives the pushover curve, in the form of force–displacement. It is a plot of base shear verses displacement.

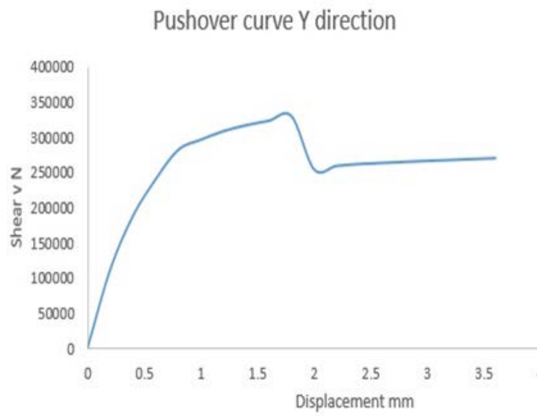


Fig 6. Pushover curve

Tabulate the shear strength values obtained from pushover curve and the parameters shear strength and eccentricity are used to plot interaction curves.

TABLE 6. Shear Strength values from Pushover curve Ey=0

Plan(Ey=0)	*Shear Strength, Y (N)*
EX=0	330367
EX=0.10	222093
EX=0.11	189622
EX=0.13	234724

TABLE 7. Shear Strength values from Pushover curve Ey=0.16

Plan(Ey=0.16)	*Shear strength, Y (N)*
EX=0	285967
EX=0.15	203204
EX=0.16	189614
EX=0.17	213683

TABLE 8. Shear Strength values from Pushover curve Ey=0.13

Plan(Ey=0.13)	*Shear strength, Y (N)*

IJSER

EX=0	292763
EX=0.15	200449
EX=0.16	197590
EX=0.17	212963

TABLE 9. Shear Strength values from Pushover curve Ey=0.10

Plan(Ey=0.10)	*Shear strength, Y (N)*
EX=0	314793
EX=0.15	206296
EX=0.16	203137
EX=0.18	232668

2.6 Interaction Curve

From the term interaction, it is clear that the diagram is used to show some interactions among the parameters in the model. The purpose of this diagram is to describe the interactive behavior of the various parameters. Here Interaction curves are developed for design purpose to visualize the interaction of shear strength and eccentricity in the seismic behavior of Unreinforced masonry buildings.
Take parameters in X axis as eccentricity in X direction divided by total wall length in Y direction and in Y axis as shear strength in Y divided by wall density in Y direction. And the curve obtained is shown in the figure.

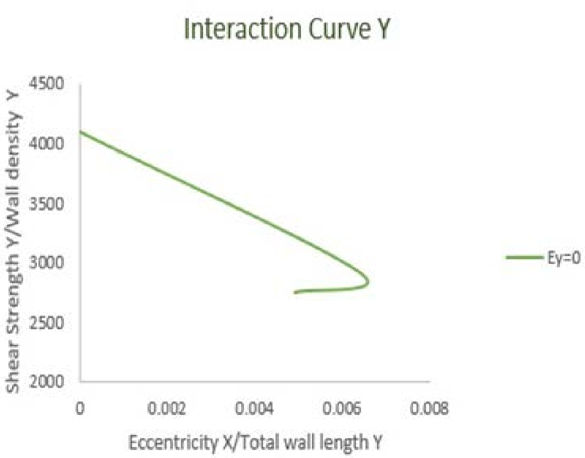


Fig.7 Interaction Curve in Y deirection Ey=0

IJSER

3 Results and Discussion

Dimensions of each wall and respective opening sizes are entered in excel sheet and calculate center of mass and center of rigidity and the difference gives the corresponding eccentricity. Eccentricity differ depends on the geometry of the structure. The parameters shear strength and eccentricity are tabulated and interaction curves are plotted.

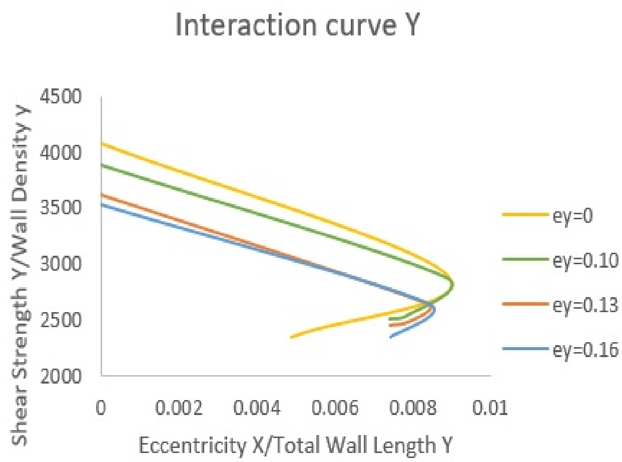


Fig.8 Interaction Curves for 600Sqft Building

4 Conclusion

The seismic analysis in TREMURI gives pushover curves which gives the base shear capacity of the building for maximum dispalcement. This work gives the seismic response of buiding with different eccentricity values. And the findings from the work are listed below.

Shear strength decreases according to the variation of plans from symmetry to unsymmetry. Buildings with zero eccentricity has high shear strength, that means the buildings fail slowly as compared to buidings with eccentricity. Wall density depends on the plan area, wall density increases the shear capacity of the building also increases. If the parameters eccentricity, wall density and total wall length of a building are known, the shear strength of the building can be find out from the interaction curve.

References

[1] Andrea Penna and Sonia Resemini (2004), Non – linear seismic analysis of masonry structures, Proceeding of 13thWorld Conference of Earthquake Engineering, Vancouver, B.C., Canada.

[2] Kamal Sonekar, S.V. Bakre (2015) Pushover analysis of Masonry Buildings.

[3] N. Augenti and A. Romano Seismic Design of masonry buildings through macro-elements.

[4] Oltion Korini and Huseyin Bilgin (2012) A new modeling approach in the pushover analysis of masonry structures.

[5] Paulo B Lourenço, Alberto Zucchini, Gabriele Milani and Antonio Tralli (2006), Homogenization approaches for structural analysis of masonry buildings, Structural analysis of Historical Constructions, New Delhi, pp 59.

[6] Pere Roca., Molins, C., and Antonio, R.M. (2005) Strength Capacity of Masonry Wall Structures by the Equivalent Frame Method, Journal of Structural Engineering, Vol. 131, pp 1601-1610.

[7] S. cattari and S. Lagomarsino (2013) Seismic assessment of mixed masonry-reinforced concrete buildings by non-linear static analyses.

[8] Serigo Lagomarsino, Andrea Penna, Alessandro Galasco, Serena Cattari (2013) TREMURI program: An equivalent frame model for the nonlinear seismic analysis of masonry buildings.

[9] Thomazevic, Earthquake resistant design of masonry buildings, series on innovation in structures and construction vol.1, 1999.

IJSER