International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 05, May - 2017

# Nonlinear Analysis of Frame Shearwall Building with Different Opening Configurations

Krishna G S
M Tech Scholar
Sree Narayana Institute of Technology
Theppupara, Adoor, Kerala

Chaithra S
Assistant Professor, Department of Civil Engineering
Sree Narayana Institute of Technology
Theppupara, Adoor, Kerala

***Abstract***— **Shear walls are the one of the most effective solution to earthquake. But while providing such shear wall architectural openings in buildings such as doors, windows etc may influence on their seismic response. This paper, summarises the application of finite element analysis in exploring the behaviour of shear wall with openings under seismic loads. This study is carried out on a ten story frame-shear wall building, with the help of finite element software ETABS, using Response Spectrum method. The comparative results showed that the, time period, top displacement, base shears, story drift and stress distributions around the openings depend on the openings arrangement system.**

***Key words- Shear Wall, Staggered Openings, Seismic Loads, Finite Element Analysis, Response Spectrum Method, ETABS***

## I. INTRODUCTION

Civil engineering structures are subjected to serious vibrations during their lifetime. Tall buildings are affected by lateral forces due to earthquakes severely. Introduction of shear walls in a building is a structurally efficient solution to stiffen the building because they provide the necessary lateral strength and stiffness to resist horizontal forces. Shear walls are usually provided along both length and width of buildings and are located at the sides of the buildings or arranged in the form of core. Many shear walls contain pattern of openings due to various functional requirements such as to accommodate doors, windows and service ducts. Such type of openings reduces the stiffness of the shear wall to some extent depending on the shape and size of the opening. Also stress distribution around the opening is critical.

Shear walls require attention because the size and location of shear walls is extremely critical.Symmetrically located shear walls performs well during earthquake because twist of the building will be small. Shear walls provide large strength and stiffness to buildings in the direction of their orientation, which significantly reduces lateral sway of the building and thereby reduces damage to structure and its contents. So it should give better results when located at exterior perimeter of the building. Properly designed and detailed buildings with shear walls have shown good performance in past earthquakes. Also the strong earthquakes recorded worldwide in the past have shown that the damages and certain failure mechanisms of shear walls depend on a series of factors such as, the shape in plan, dimensions of the walls and openings, reinforcement and the openings layout, site condition, type of earthquake and strain rates.

## II. SCOPE AND OBJECTIVES

The modern use of nonlinear analysis focuses mostly on these three fields: Virtual laboratory for parametric studies, Existing structures (evaluation, repair, and rehabilitation), Complex / stringent safety requirement structures (e.g. nuclear plants, dams, bridges)

- To find Seismic retrofit solutions
- To assess performance of building with shear wall
- Comparing different opening configuration in shear wall
- Comparing different opening sizes

## III. MODELLING AND ANALYSIS

For this study (G+10) storied, 4 × 3 bays frame-shear wall building with 5m span in both directions and floor height of 3m was modelled. Three models are analysed, model1-without opening, model2-with vertical opening and model3-with staggered opening in shear wall, using the finite element software ETABS.

Table1: Details of Model

| | |
|---|---|
| Dimension | (20x15) m |
| Shear wall thickness | 200 mm |
| Size of column | (300x600) mm |
| Size of beam | (300x600) mm |
| Slab thickness | 150 mm |
| Opening size | (2x2.225) m |
| Seismic zone | V |
| live load | 2.5 kN/m$^2$ |

The model was meshed in order to obtain results with higher accuracy. The earthquake load and load combinations were applied as per IS 1893 – 2002 and the seismic analysis was done by response spectrum method. The shear wall was designed using limit state method and was detailed as per IS 456 – 2000 and IS 13920 – 1993 respectively. Fig 1 and fig 2 shows the elevation of frame shear wall building with vertical and staggered opening respectively.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 05, May - 2017

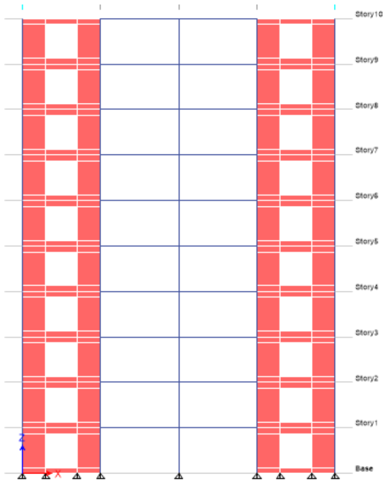

Fig1: Elevation of the Frame Shear Wall Building With Vertical Opening

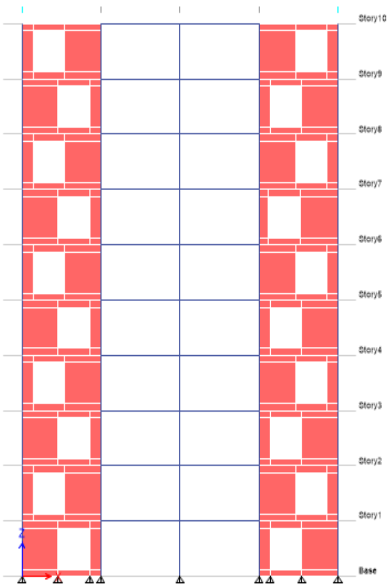

Fig 2: Elevation of the Frame-Shear Wall Building with Staggered Openings

## IV. RESULT AND DISCUSSION

### A Time period

Many mode shapes occur due to the vibratory motion of the building. But for seismic analysis, the first mode or the fundamental time period is the most significant, which is the inherent property of the building. The time period obtained from the analysis for all three models is shown in Fig. 3 and table1. It can be seen that the staggered openings exhibited a higher value of time period when compared to vertical openings, which indicates that the shear wall with staggered openings can perform better during seismic action than the vertical openings.

Table1: mode number versus time period

| MODEL | TIME PERIOD SEC | | |
|---|---|---|---|
| | MODEL 1 | MODEL 2 | MODEL 3 |
| 1 | 0.447 | 0.52 | 0.532 |
| 2 | 0.444 | 0.505 | 0.513 |
| 3 | 0.26 | 0.302 | 0.313 |
| 4 | 0.107 | 0.136 | 0.147 |
| 5 | 0.106 | 0.133 | 0.143 |
| 6 | 0.063 | 0.081 | 0.089 |
| 7 | 0.049 | 0.067 | 0.073 |
| 8 | 0.049 | 0.065 | 0.072 |
| 9 | 0.031 | 0.045 | 0.048 |
| 10 | 0.031 | 0.044 | 0.047 |
| 11 | 0.03 | 0.041 | 0.045 |
| 12 | 0.023 | 0.035 | 0.035 |

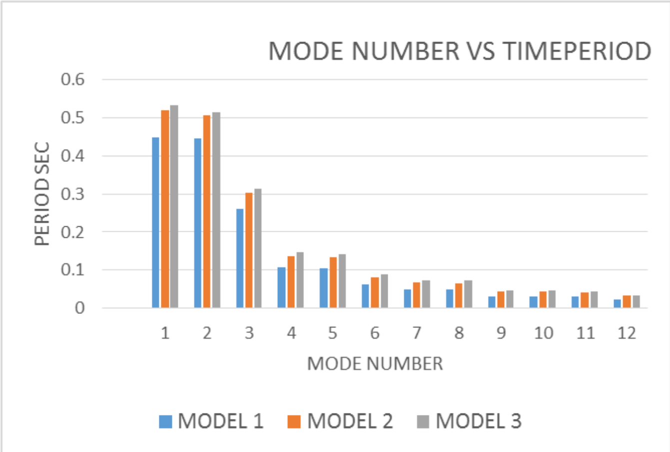


Fig3: mode number vs time period

### *B Story Displacement*

The displacement is the distance that points on the ground are moved from their initial locations by the seismic waves. Fig. 4 and table 2 display the story displacement graph in X-direction. The staggered arrangement openings gives the top displacement which agreed quit well with that induced in shear walls without openings.

Table2: story versus story displacement

| STORIES | DISPLACEMENT X-DIR (mm) | | |
|---|---|---|---|
| | MODEL 1 | MODEL 2 | MODEL 3 |
| Story10 | 7.23 | 8.883 | 8.886 |
| Story9 | 6.405 | 8.068 | 7.989 |
| Story8 | 5.547 | 7.172 | 7.004 |
| Story7 | 4.666 | 6.202 | 5.973 |
| Story6 | 3.779 | 5.178 | 4.916 |
| Story5 | 2.909 | 4.128 | 3.854 |
| Story4 | 2.084 | 3.085 | 2.834 |
| Story3 | 1.338 | 2.087 | 1.877 |
| Story2 | 0.711 | 1.183 | 1.052 |
| Story1 | 0.25 | 0.441 | 0.398 |
| Base | 0 | 0 | 0 |

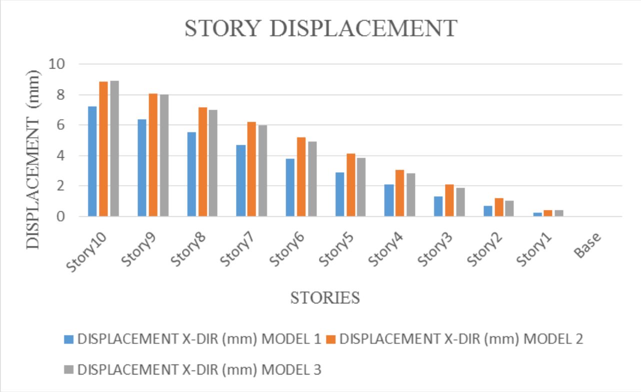


Fig 4: Story versus Story Displacement

### C Story Shear

Story shear is defined as the sum of design lateral forces at all levels above the story under consideration. The base shear is found to be much lesser for shear wall with staggered openings when compared to shear wall with vertical openings, in both the directions. As the base shear is reduced, the shear wall with staggered openings will be less susceptible to damage. Fig 5 and table 3show base shear along x direction.

Table 3: story versus story shear

| STORIES | STORY SHEAR kN | | |
|---|---|---|---|
| | MODEL 1 | MODEL 2 | MODEL 2 |
| Story10 | 326.6787 | 289.0596 | 300.0138 |
| Story9 | 649.4894 | 576.7144 | 593.8411 |
| Story8 | 910.0615 | 817.6136 | 835.4305 |
| Story7 | 1121.693 | 1019.226 | 1034.3747 |
| Story6 | 1295.085 | 1187.42 | 1199.0048 |
| Story5 | 1437.596 | 1326.651 | 1334.5084 |
| Story4 | 1552.074 | 1438.851 | 1443.8613 |
| Story3 | 1637.512 | 1523.418 | 1526.127 |
| Story2 | 1692.148 | 1578.521 | 1580.6323 |
| Story1 | 1715.982 | 1602.251 | 1604.9446 |
| Base | 1715.982 | 1602.251 | 1604.9446 |

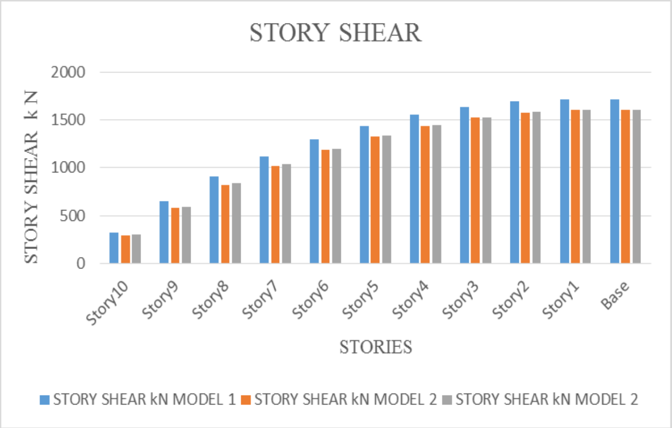


Fig 5: Story Shear versus Story

### D Story Drift

Story drift is defined as the displacement of one level relative to the other level above or below. Fig 6 and table 4 show story drift According to IS: 1893 (Part I) - 2002, the story drift for buildings is limited to 0.004 times the story height, which was not exceeded in our analytical study for all three models. In case of story drift, the shear wall with vertical as well as staggered arrangement of openings shows significant difference than solid shear wall. Story drift is more for vertical arrangement than staggered arrangement.

Table 4: story versus story drift

| STORIES | STORY DRIFT | | |
|---|---|---|---|
| | MODEL 1 | MODEL 2 | MODEL 3 |
| Story10 | 0.000276 | 0.000273 | 0.000301 |
| Story9 | 0.000287 | 0.000301 | 0.00033 |
| Story8 | 0.000295 | 0.000326 | 0.000346 |
| Story7 | 0.000297 | 0.000344 | 0.000355 |
| Story6 | 0.000291 | 0.000352 | 0.000356 |
| Story5 | 0.000276 | 0.000349 | 0.000342 |
| Story4 | 0.000249 | 0.000334 | 0.00032 |
| Story3 | 0.000209 | 0.000302 | 0.000275 |
| Story2 | 0.000154 | 0.000247 | 0.000218 |
| Story1 | 8.30E-05 | 0.000147 | 0.000133 |
| Base | 0 | 0 | 0 |

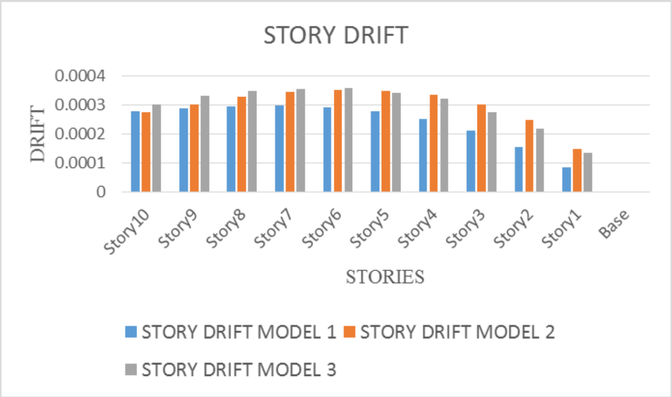


Fig 6: Story versus Story Drift

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 05, May - 2017

*E Stress Distribution*

The stress distribution of the shear wall with vertical openings and with staggered openings was studied to identify the points of higher stress accumulation and stress pattern in shear wall**.** It can be clearly seen that the stress in shear wall around the staggered openings is of much lesser intensity when compared with the stress pattern around the shear wall with vertical openings. Fig 7 and fig 8 shows the stress distribution around vertical and staggered opening shear wall.

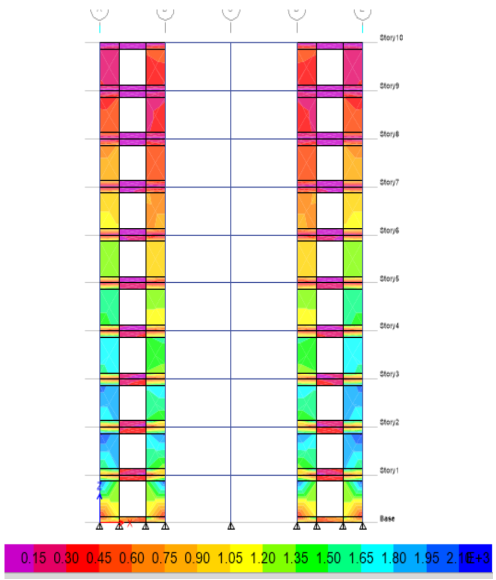


Fig 7: Stress distribution in shear wall with vertical openings

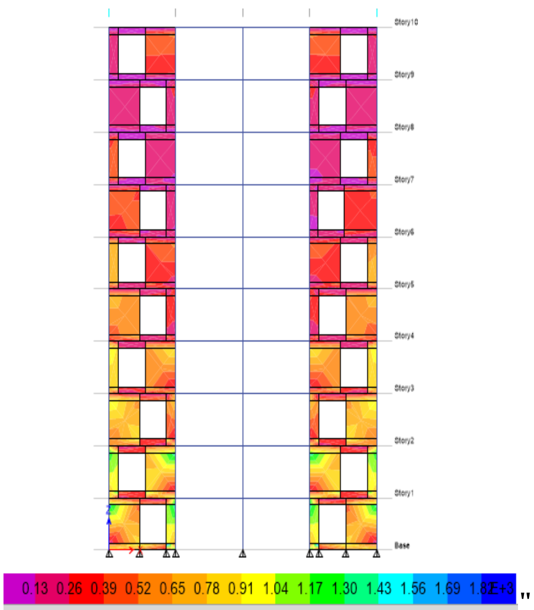


Fig 8: Stress Distribution in Shear Wall With staggered Openings

## V. CONCLUSIONS

From this study the performance of shear wall under different opening configuration has been studied. The building parameters such as story displacement, story shear, story drift, stress distribution etc are studied and compared. Finally the following conclusions are drawn,

- Presence of opening decreases strength and stiffness.
- The staggered opening gives the top displacement which agreed quit well with that induced in shear walls without openings.
- Base shear is high for staggered arrangements.
- The increase of stresses in staggered openings arrangement is small when compared to vertical arrangement of openings.
- In the economical point of view staggered opening is preferred to vertical opening.

## VI. FUTURE SCOPE

- This study could be extended by including various other parameters such as torsional effects and soft storey effects in a building.
- Seismic behaviour of different size and shape of opening can be done.

## ACKNOWLEDGMENT

We would like to acknowledge Dr.P.G.Bhaskaran Nair, PG Dean, Sree Narayana Institute of Technology, for his valuable suggestions, encouragement and findings. I thank GOD for his grace throughout the work.

## REFERENCES

[1] Aejaz Ali and James K. Wight, “R.C. structural walls with staggered door openings”, Journal of Structural Engineering, Vol. 117, No. 5, pp. 1514–1531, May. 1991.

[2] Aarthi Harini T and G. Senthil Kumar, “Behavior of R.C. Shear Wall with Staggered Openings under Seismic Loads” ,IJRT, vol2,issue 3,pp.538-611,march 2015

[3] Bergmann, R. and Pantazopoulou, V. A., (1988), "Finite Element for R/C Shear WallsUnder Cyclic Loads", Report UCB/SEMM-88/09, Department of Civil Engineering, University of California, Berkeley

[4] Hamdy H.A. Abd-el-rahim and Ahmed Abd-el-rahim Farghaly, “Influence of requisite architectural openings on shear walls efficiency”, Journal of Engineering Sciences, Assiut University, Vol. 38, No. 2, pp. 421–435, Mar. 2010

[5] Lin C.Y. and C.L. Kuo, “Behavior of shear wall with openings”, in Proc. Ninth world conference on Earthquake Engineering, Japan, pp. 535–540,1988

[6] M.Y. Kaltakci, M.H. Arslan and G. Yavuz, “Effect of Internal and External Shear Wall Location on Strengthening Weak RC Frames”, Sharif University of Technology, Vol. 17, No. 4, pp. 312-323 August 2013

[7] Shaik Kamal Mohammed Azam, Vinod Hosur ,“Seismic Performance Evaluation of Multistoried RCframed buildings with Shear wal”l, International Journal of Scientific & Engineering Research Volume 4, Issue 1, January-20

[8] P. B. Oni, Dr. S. B.Vanakudre, “Performance Based Evaluation of Shear Walled RCC Building by Pushover Analysis”, International Journal of Modern Engineering Research (IJMER) , Vol. 3, Issue. 4, pp-2522 -2525 Aug. 2013

[9] Sharmin Reza Chowdhury, M.A. Rahman, M.J. Islam and A.K. Das, “Effects of openi ngs in shear wall on seismic response of structures”‖, IJCA, Vol. 59, No. 1, pp. 10–13, Dec. 2012