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# Comparative Study of Frame Shearwall Building With Different Opening Configurations

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***Abstract***— *Shear wall buildings are a popular choice in many earthquake prone countries, like Chile, New Zealand and USA. Shear walls are efficient, both in terms of construction cost and effectiveness in minimizing earthquake damage in structural and non-structural elements. Door or window openings can be provided in shear walls. In this paper an attempt is made to analyse the effect of opening configuration and effect of opening size on the seismic behaviour of shear walls.*

*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 and also on the size of the opening.*

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

## I. INTRODUCTION

Reinforced concrete structural walls play a very important role in carrying lateral loading and resisting drift in tall buildings.The usefulness of shear walls in framing of buildings has long been recognized. Walls situated in advantageous positions in a building can form an efficient lateral-force-resisting system, simultaneously fulfilling other functional requirements. When a permanent and similar subdivision of floor areas in all stories is required as in the case of hotels or apartment buildings, numerous shear walls can be utilized not only for lateral force resistance but also to carry gravity loads`. In such case, the floor by floor repetitive planning allows the walls to be vertically continuous which may serve simultaneously as excellent acoustic and fire insulators between the apartments.

Shear walls in apartment buildings will be perforated by rows of openings that are required for windows in external walls or for doorways or corridors in internal walls. However, the size and location of openings in the shear wall may have adverse effect on seismic responses of frame-shear wall structures. Relative stiffness of shear walls is important since lateral forces are distributed to individual shear wall according to their relative stiffness. As a designer, it is necessary to know the effects of openings sizes and configurations in shear wall on stiffness as well as on seismic responses and behaviour of structural system so that a suitable configuration of openings in shear walls can be made.

## II SCOPE AND OBJECTIVES

The scope of this paper includes to get better idea on the seismic performance of building with shear wall

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

## II. 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. A further study was carried out to find best opening size. For this 3 opening size were selected which is shown in table1,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$^2$ |
| Opening sizes | (2x2.25) m<br>(1.8x1.2) m<br>(1.2x1.2) m<br>(0.9x1.2) m |

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.

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

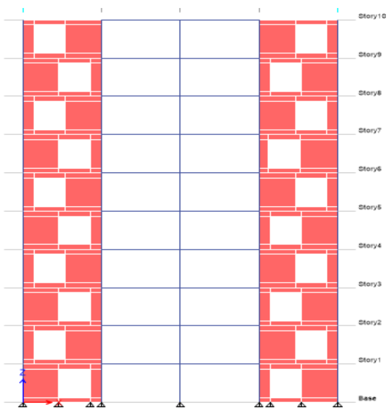


Fig 2: Elevation of the Frame-Shear Wall Building with Staggered Openings

## III. RESULT AND DISCUSSION

*1. Comparison of model 1, 2 and 3*

The tables for time period, story drift, story displacement and story shear are obtained. Corresponding graphs are plotted with the tables obtained. The tables and graph obtained are shown below.

*A Time period*

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 |

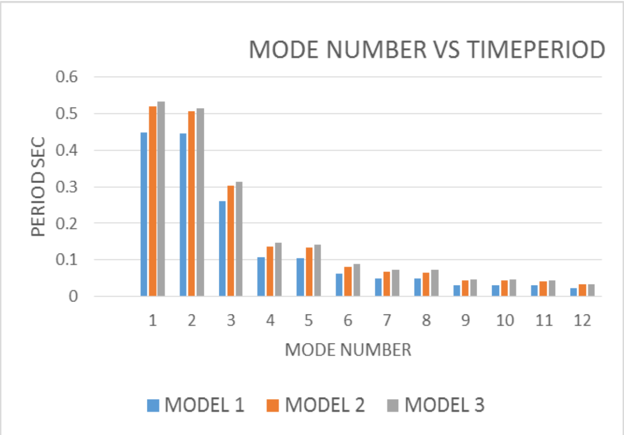



Fig3: mode number vs time period

*B Story Displacement*

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 |

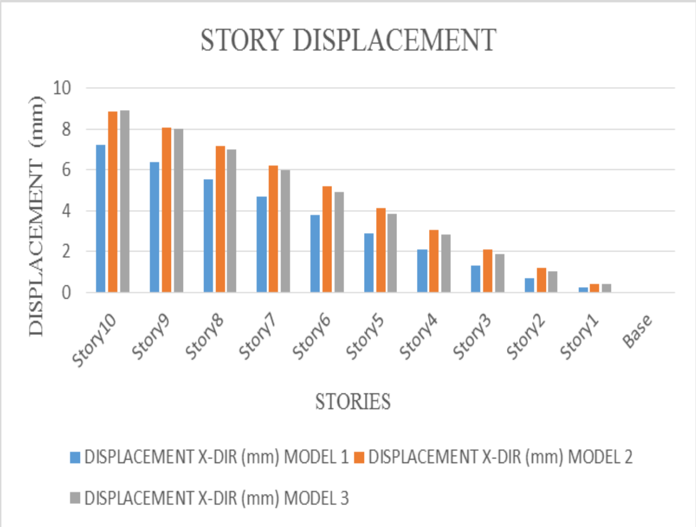



Fig 4: Story versus Story Displacement

*C Story Shear*

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 |

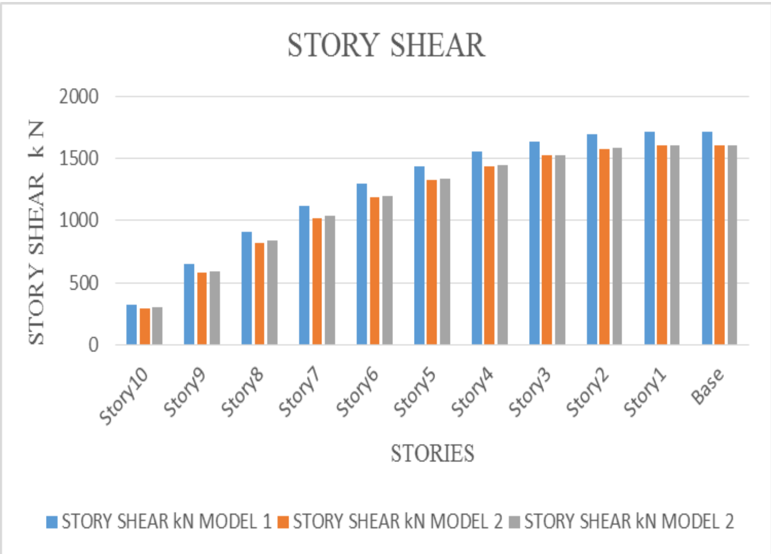



Fig 5: Story Shear versus Story

*D Story Drift*

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 |

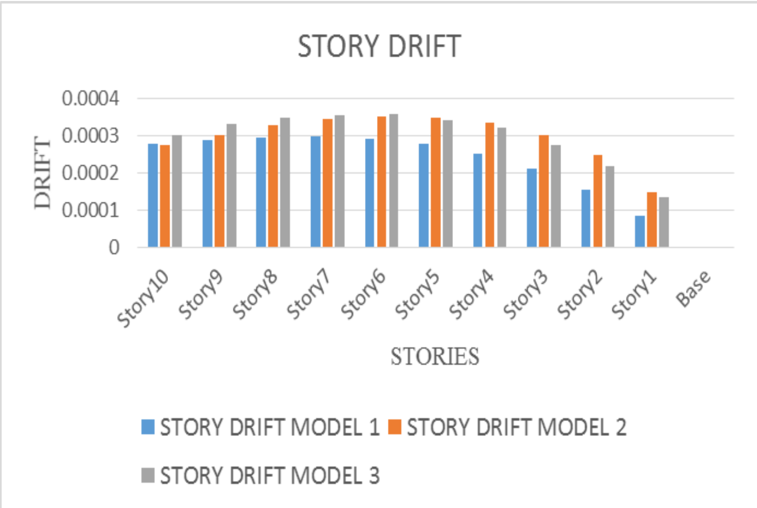


Fig 6: Story versus Story Drift

*E Stress Distribution*

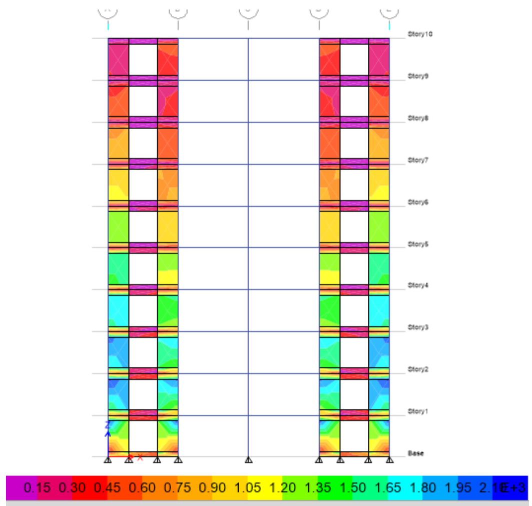


Fig 7: Stress distribution in shear wall with vertical openings

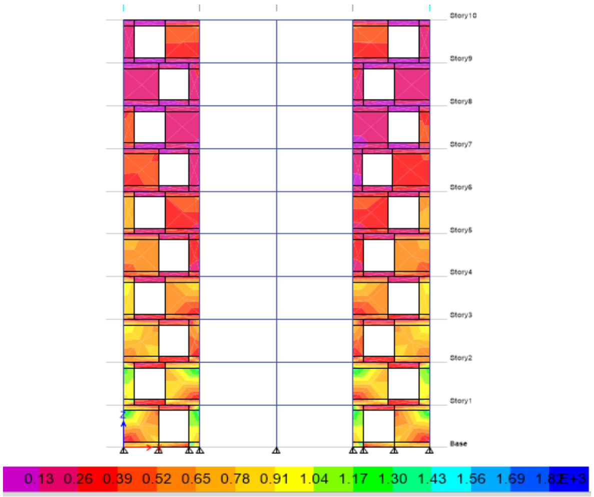


Fig 8: Stress Distribution in Shear Wall With staggered Openings

From the analysis it can be seen that story displacement in staggered opening was less as compared with vertical opening. So during earthquake it performs well. Also story shear is high in staggered arrangement.so it is less susceptible to damage. Staggered arrangement performs well during earthquake.

*2. Comparison of model with different opening sizes*

*A Time period*

Table 5: Mode number

| MODE NO. | TIME PERIOD SEC | | |
|---|---|---|---|
| | MODEL4 | MODEL5 | MODEL6 |
| 1 | 0.475 | 0.479 | 0.515 |
| 2 | 0.47 | 0.474 | 0.501 |
| 3 | 0.277 | 0.28 | 0.3 |
| 4 | 0.115 | 0.117 | 0.133 |
| 5 | 0.114 | 0.116 | 0.131 |
| 6 | 0.069 | 0.07 | 0.08 |
| 7 | 0.054 | 0.055 | 0.065 |
| 8 | 0.053 | 0.054 | 0.064 |
| 9 | 0.035 | 0.035 | 0.044 |
| 10 | 0.034 | 0.035 | 0.043 |
| 11 | 0.033 | 0.033 | 0.04 |
| 12 | 0.026 | 0.026 | 0.034 |

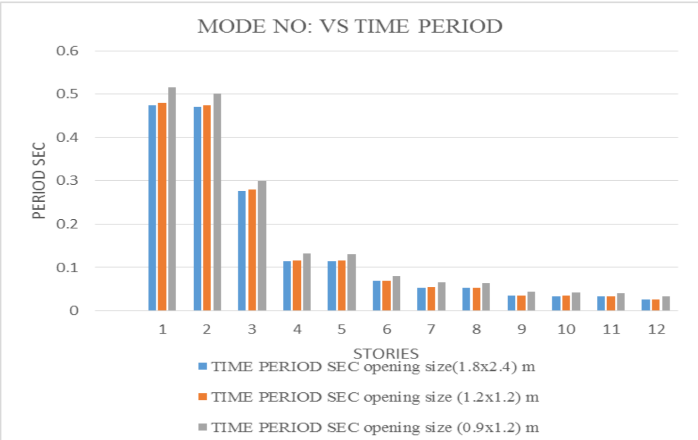



Fig 9: mode no. vs time period

*B Story displacement*

Table 6: Story vs story displacement

| STORIES | DISPLACEMENT mm | | |
|---|---|---|---|
| | **MODEL 4** | **MODEL 5** | **MODEL 6** |
| Story10 | 10.98 | 10.111 | 9.965 |
| Story9 | 9.865 | 8.983 | 8.844 |
| Story8 | 8.638 | 7.798 | 7.671 |
| Story7 | 7.36 | 6.578 | 6.464 |
| Story6 | 6.053 | 5.344 | 5.245 |
| Story5 | 4.737 | 4.126 | 4.044 |
| Story4 | 3.48 | 2.97 | 2.906 |
| Story3 | 2.299 | 1.914 | 1.869 |
| Story2 | 1.294 | 1.031 | 1.003 |
| Story1 | 0.493 | 0.368 | 0.355 |
| Base | 0 | 0 | 0 |

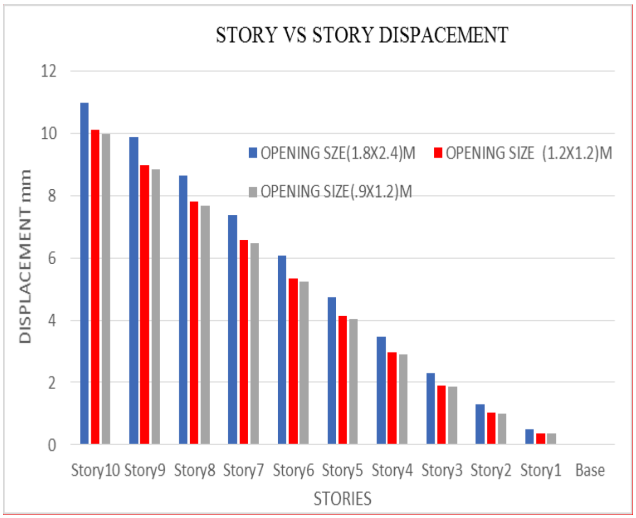



Fig 10: Story vs story displacemt

*C Story shear*

Table 6: Story vs story shear

| STORIES | STORY SHEAR k N | | |
|---|---|---|---|
| | **MODEL 4** | **MODEL 5** | **MODEL 6** |
| Story10 | 379.3045 | 401.4877 | 403.7871 |
| Story9 | 751.8276 | 794.5488 | 799.8734 |
| Story8 | 1058.0012 | 1112.9381 | 1120.262 |
| Story7 | 1309.6794 | 1372.2278 | 1380.9221 |
| Story6 | 1517.827 | 1585.1908 | 1594.8437 |
| Story5 | 1689.0042 | 1760.1265 | 1770.5654 |
| Story4 | 1827.2412 | 1900.7458 | 1911.7656 |
| Story3 | 1931.1213 | 2005.7583 | 2017.1829 |
| Story2 | 2000.3243 | 2073.8288 | 2085.3039 |
| Story1 | 2031.2693 | 2103.886 | 2115.28 |
| Base | 2031.269 | 2103.886 | 2215.28 |

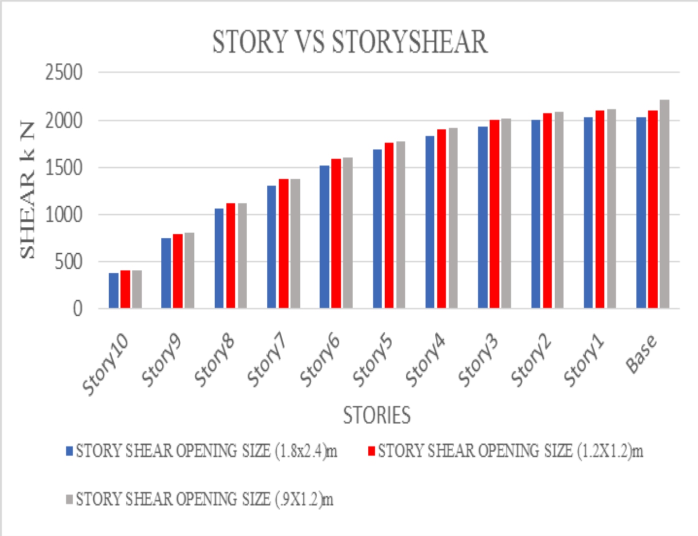



Fig 11: Story vs story displacement

*D Story drift*

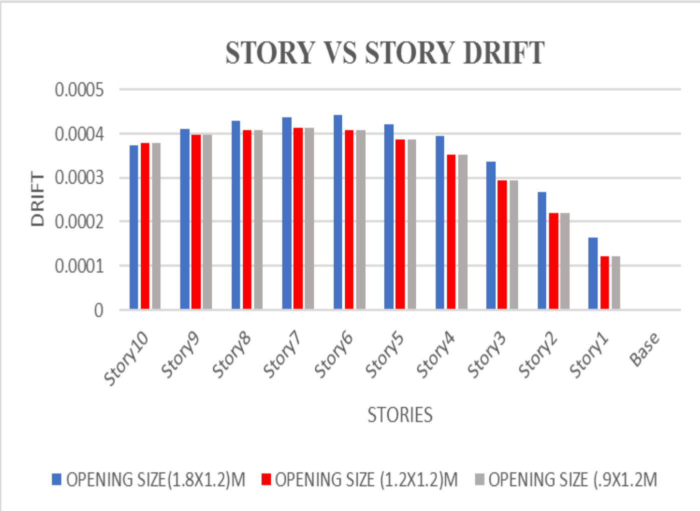


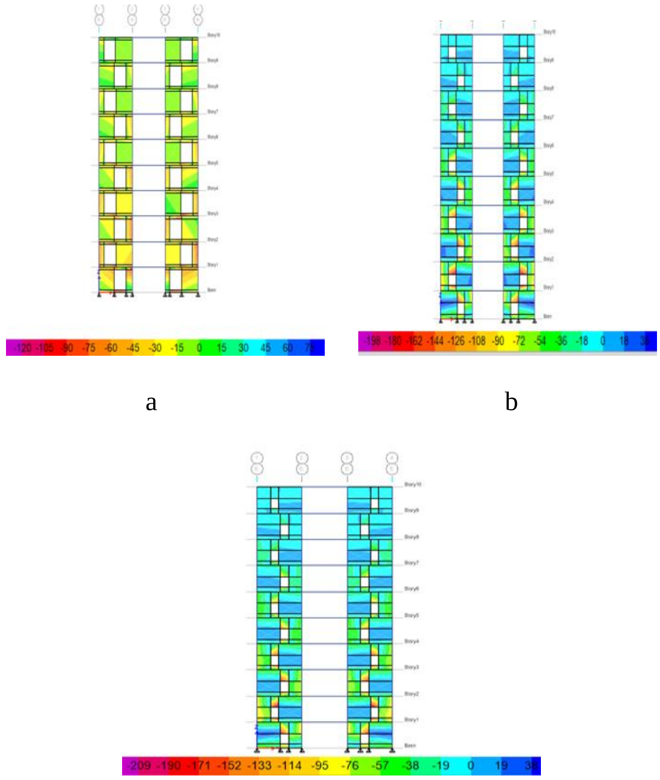

Fig 12: Story vs story drift

Table 7: Story vs story drift

| STORIES | STORY DRIFT | | |
|---|---|---|---|
| | MODEL 4 | MODEL 5 | MODEL 6 |
| Story10 | 0.000374 | 0.000378 | 0.000378 |
| Story9 | 0.000411 | 0.000397 | 0.000397 |
| Story8 | 0.000429 | 0.000409 | 0.000409 |
| Story7 | 0.000438 | 0.000413 | 0.000413 |
| Story6 | 0.000441 | 0.000408 | 0.000408 |
| Story5 | 0.000421 | 0.000386 | 0.000386 |
| Story4 | 0.000395 | 0.000353 | 0.000353 |
| Story3 | 0.000336 | 0.000295 | 0.000295 |
| Story2 | 0.000267 | 0.000221 | 0.000221 |
| Story1 | 0.000164 | 0.000123 | 0.000123 |
| Base | 0 | 0 | 0 |

*E Stress distribution*



a b

c

Fig 13: staggered opening (a) 1.8x2.4 m (b) 1.2x1.2 m (c) 0.9x1.2 m

## IV.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.
- Time period is high for staggered openings. So it is less susceptible to damage.
- 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 more preferred than vertical opening.
- Performance of the shear wall depends on the size and shape of the opening
- As opening increases bottom stresses first increases proportionally, there after Stress increases vastly.
- Effective Opening size selected was (0.9x1.2) m.

## IV. FUTURE SCOPE

- This study could be extended by including various other parameters such as torsional effects and soft story effects in a building.
- In the present study, types of shear wall is not considered. Therefore work can be repeated by type of shear wall
- The study of changing position of shear wall with openings can be done by variation of shape and sizes of openings

## ACKNOWLEDGMENT

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