

Comperative Study of Opening in Shear Wall

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Abstract: The use of shear wall-buildings is quite common in some earthquake prone regions. During seismic excitation, they contribute in absorbing moments and shear forces and reduce torsional response. Usually, architectural design leads to the existence of doors and windows within shear walls. In this present study the main focus is to determine the effectiveness of shear wall with regular and staggered opening in regular building under earthquake loads with the help of time history method of analysis on ETABS software.

1. INTRODUCTION

Shear walls contribute to significant lateral stiffness, strength, and overall ductility and energy dissipation capacity. Shear wall is widely adopted because of its strength, stability and stiffness to resist lateral loads. They have considerable stiffness in their own plane but usually very little stiffness in the perpendicular direction and their satisfactory performance depends on the stiffening effect of floor diaphragms, which prevent buckling of walls. In many shear walls a regular pattern of openings has to be provided due to various functional requirements such as to accommodate doors, windows and service ducts.

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.

2. BUILDING DISCRIPTION:

| | Structural Part | Dimension |
|----|----------------------------|-------------------------|
| 1. | Type of building | Office purpose building |
| 2. | Location of building | Palwal, Haryana India |
| 3. | Length in X-direction | 48m |
| 4. | Length in Y-direction | 36m |
| 5. | No. of bays in X-direction | 8 No. @ 6m |

| | | |
|-----|------------------------------|---|
| 6. | No. of bays in Y-direction | 6 No. @ 6m |
| 7. | No. of storey | 30m |
| 8. | Floor to floor height | 3m |
| 9. | Bottom Storey height | 3.5m |
| 10. | Total height of building | 90.5m |
| 11. | Slab thickness | 150mm |
| 12. | Column size | 450x450mm(1-15 storey) 350X350mm(16-30 storey) |
| 13. | Beam Size | 350x450mm |
| 14. | Large Opening size | 2000x2000mm |
| 15. | Small Opening size | 1000x2000mm |
| 16. | Thickness of Shear Wall | 200mm |
| 17. | Length of Shear wall in Plan | 6m |
| 18. | Live Load on slab | 3.5 kN/m ² |

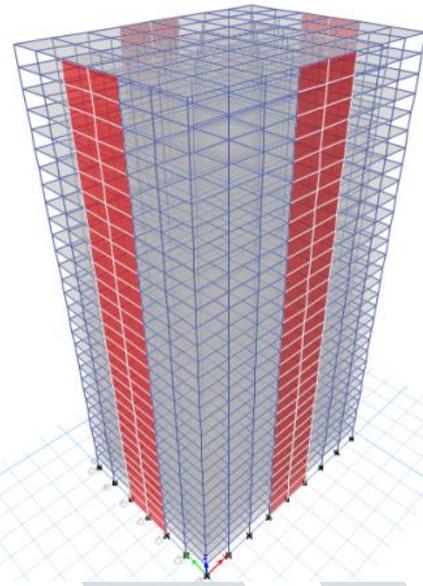
2.2. Material Properties

| S. No. | Material | Grade |
|--------|-------------------|----------|
| 1. | Concrete (beam) | M25 |
| 2. | Concrete (column) | M30 |
| 3. | Concrete (slab) | M25 |
| 4. | Rebar | HYSD-415 |

2.3. Seismic Data

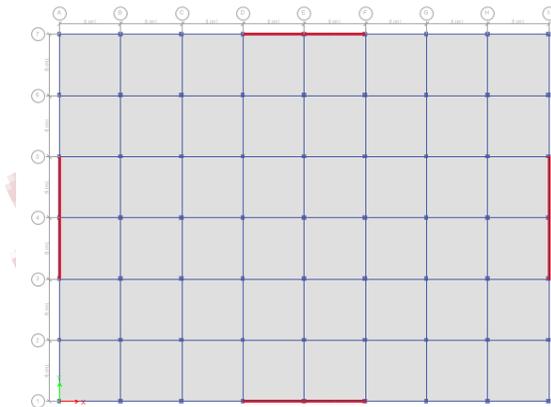
| | |
|-----------------|----------|
| Zone Factor (Z) | IV (.24) |
|-----------------|----------|

| | |
|------------------------------|--|
| Importance Factor(I) | 1.5 |
| Response Reduction Factor(R) | 5 |
| Soil Type | II (Medium Soil) |
| Damping | 5% |
| Code used for analysis | IS 1893:2002 IS 456:2000 IS 800:2007 |
| Time history data used | Palwal (Delhi Haryana region) |



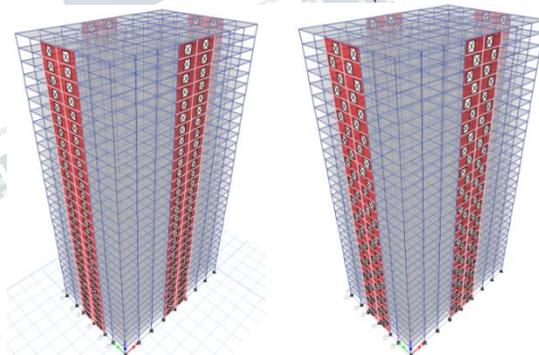
3D Model of Building

SHEAR WALL LOCATED AT SIDE CENTRE WITHOUT OPENING



Plan of building

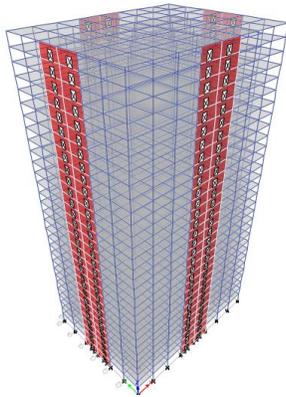
SHEARWALL LOCATED AT SIDE CENTRE WITH LARGE OPENING SIZE (2000x2000mm)



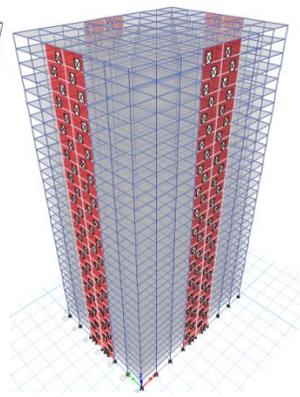
Regular Opening 3D View

Staggered Opening

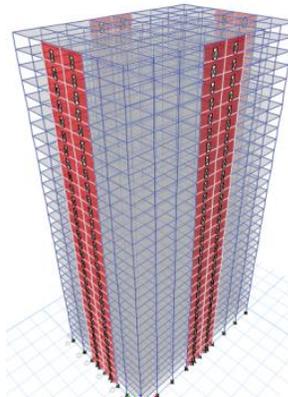
HEARWALL LOCATED AT SIDE CENTRE WITH MEDIUM OPENING SIZE (1500x2000mm)



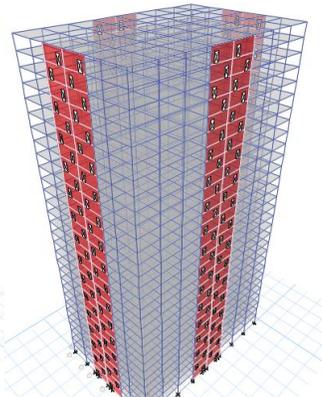
REGULAR OPENING



STAGGERED OPENING



REGULAR OPENING



STAGGERED OPENING

**SHEARWALL LOCATED AT SIDE CENTRE
WITH SMALL OPENING SIZE (1000x2000mm)**

Natural Time Period:

Fundamental natural period T is an inherent property of a building. Any alterations made to the building will change its T. Fundamental natural periods T of normal range 0.03-33 sec.

Table: Natural Time Period

| | Without Opening | Large Opening | | Medium Opening | | Small Opening | |
|--------|-----------------|---------------|----------|----------------|---------|---------------|---------|
| Mode | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 |
| | sec | sec | sec | sec | sec | sec | sec |
| Mode 1 | 3.92 | 1.09E+08 | 35661184 | 3.227 | 3.705 | 3.313 | 3.473 |
| Mode 2 | 3.857 | 39159946 | -2.7E+07 | 3.174 | 3.644 | 3.278 | 3.403 |
| Mode 3 | 2.705 | -2.7E+07 | 22113960 | 2.234 | 2.55 | 2.268 | 2.341 |
| Mode 4 | 0.997 | -2.7E+07 | 20551188 | 0.847 | 0.97 | 0.871 | 0.921 |
| Mode 5 | 0.991 | -2.7E+07 | 19411639 | 0.842 | 0.965 | 0.86 | 0.9 |
| Mode 6 | 0.645 | -2.1E+07 | -1.7E+07 | 0.551 | 0.627 | 0.566 | 0.586 |
| Mode 7 | 0.435 | -2E+07 | -1.6E+07 | 0.375 | 0.43 | 0.395 | 0.41 |
| Mode 8 | 0.435 | -1.6E+07 | -1.6E+07 | 0.375 | 0.429 | 0.393 | 0.403 |
| Mode 9 | 0.274 | 15871944 | 14391610 | 0.236 | 0.269 | 0.249 | 0.254 |

| | | | | | | | |
|---------|-------|----------|----------|-------|-------|-------|-------|
| Mode 10 | 0.254 | 13631368 | 13076043 | 0.221 | 0.253 | 0.235 | 0.241 |
| Mode 11 | 0.254 | 13186268 | 12398674 | 0.22 | 0.252 | 0.234 | 0.239 |
| Mode 12 | 0.174 | -1.3E+07 | 12016247 | 0.151 | 0.173 | 0.162 | 0.165 |

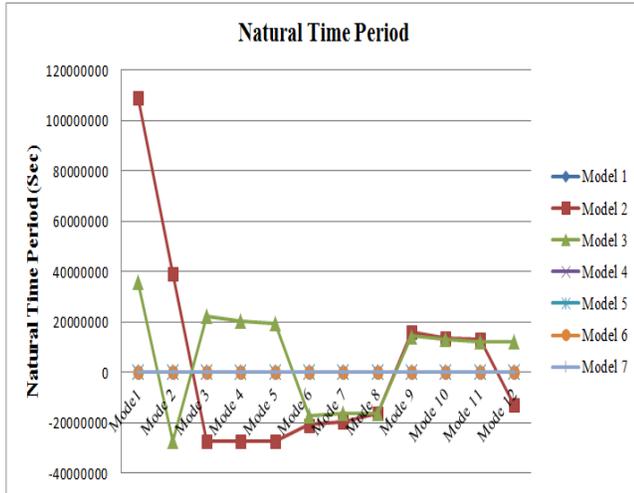


Figure: Natural Time Period of different models

Story Displacement

According to IS Code 1893-2002, the maximum allowable story displacement is calculated as $h/250$, where 'h' is height of building above the ground level.

Story Displacement = $90500/250=362\text{mm}$

In without opening (model 1) the maximum displacement value with in the permissible value of IS code. So, the structure is safe in story displacement.

Table: Story Displacement in 'X' direction

| Story | Without Opening | Large Opening Size (2000x2000mm) | | Medium Opening Size (1500x2000mm) | | Small Opening Size (1000x2000mm) | |
|---------|-----------------|----------------------------------|----------|-----------------------------------|---------|----------------------------------|---------|
| | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 |
| | mm | mm | mm | mm | mm | mm | mm |
| Story30 | 177.121 | 1492.724 | 1329.843 | 145.342 | 166.622 | 145.843 | 157.11 |
| Story29 | 170.747 | 1439.169 | 1283.343 | 140.246 | 160.775 | 141.2 | 151.617 |
| Story28 | 164.263 | 1384.669 | 1235.942 | 135.053 | 154.815 | 136.43 | 146.017 |
| Story27 | 157.678 | 1329.312 | 1187.677 | 129.766 | 148.749 | 131.557 | 140.315 |
| Story26 | 150.975 | 1272.955 | 1138.406 | 124.37 | 142.558 | 126.56 | 134.494 |
| Story25 | 144.149 | 1215.544 | 1088.072 | 118.858 | 136.235 | 121.43 | 128.548 |
| Story24 | 137.199 | 1157.079 | 1036.668 | 113.231 | 129.78 | 116.165 | 122.476 |

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| | | | | | | | |
|---------|---------|----------|---------|---------|---------|---------|---------|
| Story23 | 130.133 | 1097.613 | 984.24 | 107.493 | 123.199 | 110.765 | 116.282 |
| Story22 | 122.961 | 1037.244 | 930.876 | 101.654 | 116.502 | 105.236 | 109.978 |
| Story21 | 115.7 | 976.114 | 876.708 | 95.729 | 109.707 | 99.588 | 103.579 |
| Story20 | 108.373 | 914.404 | 821.906 | 89.735 | 102.834 | 93.832 | 97.105 |
| Story19 | 101.004 | 852.33 | 766.672 | 83.696 | 95.91 | 87.987 | 90.579 |
| Story18 | 93.624 | 790.144 | 711.243 | 77.637 | 88.963 | 82.071 | 84.031 |
| Story17 | 86.265 | 728.129 | 655.888 | 71.587 | 82.027 | 76.106 | 77.491 |
| Story16 | 78.967 | 666.607 | 600.909 | 65.579 | 75.14 | 70.118 | 70.996 |
| Story15 | 71.753 | 605.775 | 546.503 | 59.636 | 68.327 | 64.128 | 64.568 |
| Story14 | 64.77 | 546.892 | 494.021 | 53.903 | 61.757 | 58.184 | 58.368 |
| Story13 | 57.908 | 489.009 | 442.37 | 48.263 | 55.292 | 52.295 | 52.265 |
| Story12 | 51.225 | 432.629 | 392.002 | 42.763 | 48.99 | 46.501 | 46.314 |
| Story11 | 44.751 | 378.004 | 343.129 | 37.428 | 42.876 | 40.834 | 40.54 |
| Story10 | 38.523 | 325.441 | 296.015 | 32.285 | 36.983 | 35.334 | 34.974 |
| Story9 | 32.579 | 275.27 | 250.949 | 27.367 | 31.348 | 30.04 | 29.649 |
| Story8 | 26.963 | 227.847 | 208.246 | 22.708 | 26.009 | 24.995 | 24.604 |
| Story7 | 21.718 | 183.557 | 168.253 | 18.344 | 21.011 | 20.25 | 19.879 |
| Story6 | 16.894 | 142.814 | 131.345 | 14.318 | 16.399 | 15.84 | 15.518 |
| Story5 | 12.545 | 106.067 | 97.934 | 10.675 | 12.225 | 11.844 | 11.57 |
| Story4 | 8.726 | 73.795 | 68.466 | 7.461 | 8.544 | 8.303 | 8.089 |
| Story3 | 5.499 | 46.519 | 43.43 | 4.732 | 5.418 | 5.284 | 5.131 |
| Story2 | 2.931 | 24.802 | 23.364 | 2.545 | 2.914 | 2.854 | 2.76 |
| Story1 | 1.09 | 9.232 | 8.834 | 0.962 | 1.101 | 1.086 | 1.044 |

Table: Story Displacement in 'Y' direction

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| Story | Without Opening | Large Opening Size (2000x2000mm) | | Medium Opening Size (1500x2000mm) | | Small Opening Size (1000x2000mm) | |
|---------|-----------------|-------------------------------------|----------|--------------------------------------|---------|-------------------------------------|---------|
| | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 |
| | mm | mm | mm | mm | mm | mm | mm |
| Story30 | 186.679 | 1492.509 | 1347.453 | 153.37 | 175.82 | 148.967 | 162.494 |
| Story29 | 179.867 | 1438.304 | 1299.393 | 147.906 | 169.55 | 144.163 | 156.698 |
| Story28 | 172.943 | 1383.177 | 1250.45 | 142.343 | 163.168 | 139.23 | 150.797 |
| Story27 | 165.919 | 1327.205 | 1200.661 | 136.687 | 156.679 | 134.193 | 144.793 |
| Story26 | 158.778 | 1270.258 | 1149.899 | 130.923 | 150.066 | 129.032 | 138.672 |
| Story25 | 151.514 | 1212.294 | 1098.122 | 125.044 | 143.322 | 123.74 | 132.428 |
| Story24 | 144.129 | 1153.328 | 1045.337 | 119.052 | 136.449 | 118.314 | 126.063 |
| Story23 | 136.631 | 1093.422 | 991.602 | 112.951 | 129.451 | 112.756 | 119.583 |
| Story22 | 129.03 | 1032.685 | 937.021 | 106.752 | 122.343 | 107.073 | 113.002 |
| Story21 | 121.346 | 971.267 | 881.733 | 100.471 | 115.14 | 101.276 | 106.335 |
| Story20 | 113.602 | 909.355 | 825.917 | 94.128 | 107.866 | 95.378 | 99.604 |
| Story19 | 105.823 | 847.172 | 769.785 | 87.744 | 100.547 | 89.397 | 92.835 |
| Story18 | 98.04 | 784.971 | 713.577 | 81.348 | 93.213 | 83.352 | 86.057 |
| Story17 | 90.29 | 723.038 | 657.566 | 74.969 | 85.901 | 77.265 | 79.302 |
| Story16 | 82.61 | 661.693 | 602.055 | 68.641 | 78.647 | 71.161 | 72.608 |
| Story15 | 75.026 | 601.144 | 547.253 | 62.388 | 71.479 | 65.067 | 65.999 |
| Story14 | 67.684 | 542.614 | 494.477 | 56.353 | 64.563 | 59.015 | 59.634 |
| Story13 | 60.474 | 485.155 | 442.637 | 50.422 | 57.765 | 53.03 | 53.382 |
| Story12 | 53.46 | 429.239 | 392.151 | 44.644 | 51.143 | 47.146 | 47.294 |
| Story11 | 46.671 | 375.102 | 343.222 | 39.044 | 44.726 | 41.397 | 41.393 |

| | | | | | | | |
|---------|--------|---------|---------|--------|--------|--------|--------|
| Story10 | 40.145 | 323.036 | 296.101 | 33.652 | 38.548 | 35.821 | 35.71 |
| Story9 | 33.924 | 273.354 | 251.063 | 28.5 | 32.645 | 30.457 | 30.278 |
| Story8 | 28.051 | 226.398 | 208.41 | 23.625 | 27.06 | 25.349 | 25.134 |
| Story7 | 22.573 | 182.537 | 168.474 | 19.066 | 21.837 | 20.541 | 20.318 |
| Story6 | 17.542 | 142.172 | 131.62 | 14.865 | 17.024 | 16.086 | 15.873 |
| Story5 | 13.01 | 105.738 | 98.246 | 11.067 | 12.675 | 12.039 | 11.848 |
| Story4 | 9.037 | 73.704 | 68.79 | 7.724 | 8.845 | 8.453 | 8.296 |
| Story3 | 5.685 | 46.583 | 43.733 | 4.889 | 5.598 | 5.391 | 5.274 |
| Story2 | 3.022 | 24.935 | 23.608 | 2.623 | 3.002 | 2.922 | 2.847 |
| Story1 | 1.119 | 9.347 | 8.982 | 0.987 | 1.13 | 1.118 | 1.083 |

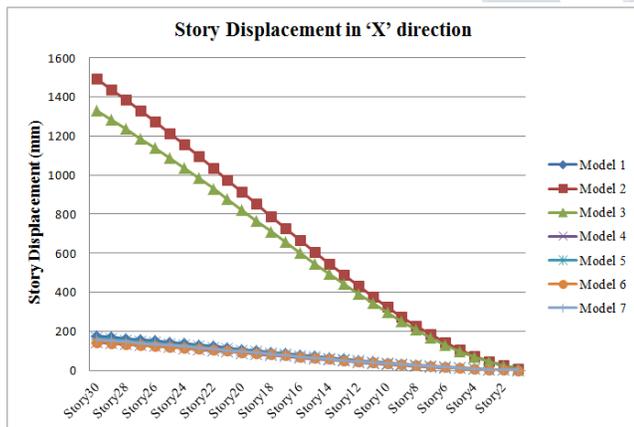


Figure: Story Displacement in 'X' direction

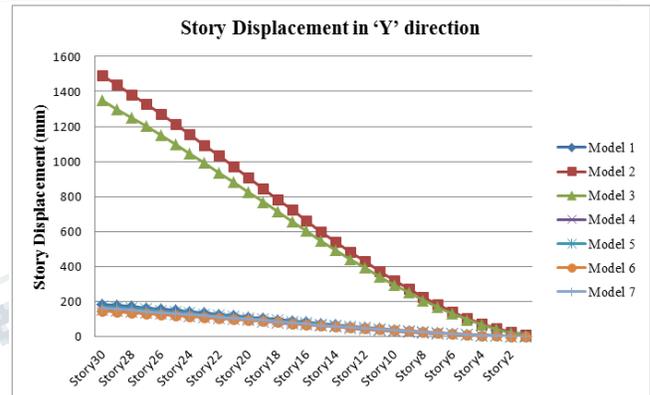


Figure: Story Displacement in 'Y' direction

Story Stiffness

A soft story is one in which the lateral stiffness is less than 70 percent of that in the story above or less than 80 percent of the lateral stiffness of three story above. Lowest value of story stiffness shows that structure is flexible and higher story stiffness shows the structure is stiffer. Stiffness regularity in elevation required by seismic design codes.

Table: Story Stiffness in 'X' Direction

| | | | | |
|--|------------------------|---|----------------------------|---------------------------|
| | Without Opening | Large Opening Size (2000x2000mm) | Medium Opening Size | Small Opening Size |
|--|------------------------|---|----------------------------|---------------------------|

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| Story | | | | (1500x2000mm) | | (1000x2000mm) | |
|---------|----------|---------|---------|---------------|----------|---------------|----------|
| | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 |
| | kN/m | kN/m | kN/m | kN/m | kN/m | kN/m | kN/m |
| Story30 | 114931.2 | 0 | 0 | 131057.1 | 133009.5 | 168539.6 | 133011 |
| Story29 | 224761.4 | 0 | 0 | 259002 | 260755.3 | 331946.5 | 261183.8 |
| Story28 | 323953.2 | 0 | 0 | 372936.2 | 375392.3 | 476416.3 | 376175 |
| Story27 | 411992.1 | 0 | 0 | 473441.6 | 476419.9 | 601871.2 | 477470.2 |
| Story26 | 489834.3 | 0 | 0 | 561665 | 565033 | 709987.7 | 566269.2 |
| Story25 | 558574.7 | 0 | 0 | 639057.1 | 642642.4 | 802771.4 | 643995.6 |
| Story24 | 619478.6 | 0 | 0 | 707225 | 710862 | 882397.4 | 712268.9 |
| Story23 | 673853.7 | 0 | 0 | 767803.6 | 771329.2 | 951025.8 | 772741.4 |
| Story22 | 722995 | 0 | 0 | 822384.6 | 825652.7 | 1010690 | 827026 |
| Story21 | 768157.6 | 0 | 0 | 872496.7 | 875362.9 | 1063258 | 876664.6 |
| Story20 | 810557 | 0 | 0 | 919581.5 | 921932.7 | 1110423 | 923131.2 |
| Story19 | 851379.1 | 0 | 0 | 965162.4 | 966777.3 | 1153736 | 967848.5 |
| Story18 | 891826 | 0 | 0 | 1010275 | 1011342 | 1194608 | 1012258 |
| Story17 | 933281.4 | 0 | 0 | 1056658 | 1057189 | 1234366 | 1057932 |
| Story16 | 974607.9 | 0 | 0 | 1115659 | 1103232 | 1274784 | 1103750 |
| Story15 | 1035493 | 0 | 0 | 1175670 | 1176514 | 1316772 | 1176676 |
| Story14 | 1078749 | 0 | 0 | 1227461 | 1224342 | 1361252 | 1224353 |
| Story13 | 1130101 | 0 | 0 | 1285042 | 1281146 | 1410734 | 1281014 |
| Story12 | 1186261 | 0 | 0 | 1348236 | 1342872 | 1467034 | 1342583 |
| Story11 | 1250153 | 0 | 0 | 1419766 | 1412656 | 1532804 | 1412211 |
| Story10 | 1324791 | 0 | 0 | 1503151 | 1493820 | 1611594 | 1493209 |

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|--------|---------|---------|---------|---------|---------|---------|---------|
| Story9 | 1414465 | 0 | 0 | 1603253 | 1591003 | 1708402 | 1590223 |
| Story8 | 1525436 | 0 | 0 | 1727201 | 1710978 | 1829700 | 1710010 |
| Story7 | 1667334 | 0 | 0 | 1885985 | 1864087 | 1993677 | 1862920 |
| Story6 | 1855919 | 0 | 0 | 2097702 | 2067228 | 2202094 | 2065822 |
| Story5 | 2119067 | 0 | 0 | 2394442 | 2350102 | 2502692 | 2348422 |
| Story4 | 2511296 | 0 | 0 | 2840624 | 2770544 | 2956997 | 2768490 |
| Story3 | 3156775 | 0 | 0 | 3608294 | 3459121 | 3754418 | 3456564 |
| Story2 | 4403208 | 4404080 | 4772661 | 4777800 | 4777009 | 4927215 | 4773614 |
| Story1 | 7421213 | 7422186 | 7841402 | 7847166 | 7847274 | 8010550 | 7842977 |

Table: Story Stiffness in 'Y' Direction

| Story | Without Opening | Large Opening Size (2000x2000mm) | | Medium Opening Size (1500x2000mm) | | Small Opening Size (1000x2000mm) | |
|---------|-----------------|----------------------------------|---------|-----------------------------------|----------|----------------------------------|----------|
| | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 |
| | kN/m | kN/m | kN/m | kN/m | kN/m | kN/m | kN/m |
| Story30 | 109461.1 | 0 | 0 | 124449 | 126283.6 | 166176.9 | 135379.2 |
| Story29 | 214252.3 | 0 | 0 | 246188.5 | 247826.6 | 327880.3 | 266051.4 |
| Story28 | 309086.3 | 0 | 0 | 354883.9 | 357171.5 | 471044.7 | 383468.4 |
| Story27 | 393508.5 | 0 | 0 | 451115.3 | 453882.6 | 595943.4 | 487254.7 |
| Story26 | 468411.5 | 0 | 0 | 535939.2 | 539063.1 | 704211.3 | 578661.6 |
| Story25 | 534806.5 | 0 | 0 | 610685.9 | 614004.5 | 797829.5 | 659133.2 |
| Story24 | 593864.1 | 0 | 0 | 676831.3 | 680187.9 | 878919.1 | 730295.7 |
| Story23 | 646797.1 | 0 | 0 | 735882.7 | 739122 | 949577.6 | 793798.6 |
| Story22 | 694811.2 | 0 | 0 | 789315.3 | 792296.5 | 1011780 | 851251.3 |
| Story21 | 739081.4 | 0 | 0 | 838554 | 841136.7 | 1067346 | 904196.7 |
| Story20 | 780750.7 | 0 | 0 | 884951.5 | 887023.3 | 1117942 | 954118.3 |
| Story19 | 820941.2 | 0 | 0 | 929943.3 | 931290.8 | 1165105 | 1002461 |
| Story18 | 860794.2 | 0 | 0 | 974525.8 | 975308 | 1210279 | 1050704 |

| | | | | | | | |
|---------|----------|---------|---------|---------|---------|---------|---------|
| Story17 | 901631.7 | 0 | 0 | 1020314 | 1020567 | 1254885 | 1100458 |
| Story16 | 942438.8 | 0 | 0 | 1077409 | 1066105 | 1301800 | 1150830 |
| Story15 | 1001052 | 0 | 0 | 1136089 | 1136523 | 1348650 | 1229530 |
| Story14 | 1043815 | 0 | 0 | 1186969 | 1183894 | 1398171 | 1281661 |
| Story13 | 1094315 | 0 | 0 | 1243679 | 1239845 | 1452173 | 1342703 |
| Story12 | 1149618 | 0 | 0 | 1305972 | 1300741 | 1512940 | 1408786 |
| Story11 | 1212559 | 0 | 0 | 1376514 | 1369622 | 1583090 | 1483105 |
| Story10 | 1286089 | 0 | 0 | 1458747 | 1449740 | 1666256 | 1569105 |
| Story9 | 1374420 | 0 | 0 | 1557438 | 1545652 | 1768045 | 1671600 |
| Story8 | 1483700 | 0 | 0 | 1679580 | 1664012 | 1888042 | 1797581 |
| Story7 | 1623397 | 0 | 0 | 1835973 | 1814998 | 2069188 | 1957744 |
| Story6 | 1809026 | 0 | 0 | 2044405 | 2015256 | 2290447 | 2169497 |
| Story5 | 2068048 | 0 | 0 | 2336462 | 2294080 | 2601409 | 2463424 |
| Story4 | 2454248 | 0 | 0 | 2775531 | 2708590 | 3068203 | 2898834 |
| Story3 | 3090342 | 0 | 0 | 3499982 | 3387983 | 3833541 | 3609268 |
| Story2 | 4321047 | 4600287 | 4959710 | 4691684 | 4690855 | 5090047 | 4960716 |
| Story1 | 7325334 | 7649942 | 8048880 | 7751791 | 7751825 | 8188429 | 8050514 |

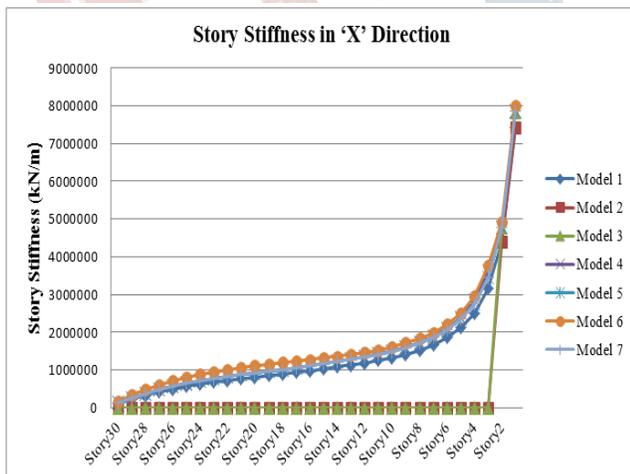


Figure:Story Stiffness in 'X' Direction

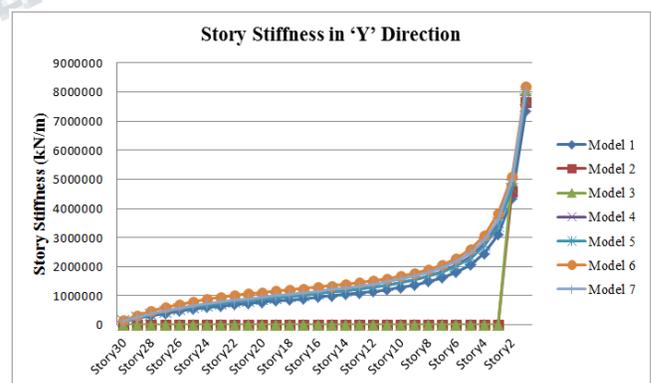


Figure:Story Stiffness in 'Y' Direction

CONCLUSIONS:

In the present study, Time History Method of analysis of reinforced concrete buildings by changing position of shear

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wall with opening is carried out for different storey heights. The size of openings in shear wall is changed. The buildings are analysed for earthquake load (seismic zone IV).

From the results it is concluded that for opening area < 20% of shear wall area, the stiffness of shear-wall structure is more affected by the size of openings than their arrangement in the shear walls.

In large opening of both regular and staggered (Model 2 & Model 3), the value of maximum displacement exceeds the permissible limit. So, structure fails in storey displacement. Story Stiffness in Model 2 and Model 3 are reduced to zero above 2nd story up to top story. So model 2 and model 3 failed in case of story stiffness. Model 2 and Model 3 contains 22.22% opening in shear wall.

For opening area > 20% of shear wall area, the stiffness of the system is significantly affected by the openings arrangement in shear walls.

Presence of opening decreases strength and stiffness . 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

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