Effect Of Seismic and Wind Behaviour on Multi-Storey Buildings with Circular, Hollow Rectangular And C-Shaped Plan

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***Abstract*—Nowadays, construction of high-rised buildings is in highly in demand. Wherein if go on constructing taller buildings, then they get affected by seismic and wind forces. Henceforth, there is a need to safeguard structures from such loads. So, we need to do a proper study on changing plan configurations and getting strength wise and economically suitable structures. Also, we can vary different parameters such as drift, acceleration, time period, etc. to get proper output. This study will be based on studies of different scholar related to this topic. Wherein shape giving minimal possible parameters needs to be selected. So mostly it is said that plan configuration is of due importance and that too needs to be done with considering all the constraints. The earthquake is been considered most important aspect for designing. There can be comparison made on the basis of regular and irregular plan shapes. It has been observed that the irregular shape shows different results for seismic forces. The configuration when varied it shows immense behaviour. When compared, different parameters show diversified results. More the simpler plan there will be more efficient output provided**

Index Terms*—Earthquake, Multi-storey Building, Wind Analysis.

I. INTRODUCTION

Nowadays multi-storied buildings are widely adopted in urban areas all over the world due to the drastic increase in urban population, scarcity of land and its high cost. But challenge is that as the height of structure increases vertically it is affected by lateral loads. These lateral loads are mainly the form of wind load and earthquake load. So, effective design approach and advance construction techniques are adopted to protect the tall buildings from wind load and earthquake load. Many researches and studies have been done to improve the performance of tall buildings against these loads. Most important and effective design approach among these methods is modification of plan shape geometry of building and also it is very simple and not requires much more techniques. In the past mostly, rectangular plan shape was adopted, but today much more different plan shapes are utilized. So, it is necessary to study the behavior of buildings with different plan shapes and compare them in terms of different parameters and thereby finding most suitable plan shape.

II. CORRESPONDING LITERATURE

Akash S. Waghmode *et al*. (2016) [1] carried out the wind analysis of G+15 shear wall structure with J shape and rectangular shape using Etabs 2015 software and IS 875:1987(part 3). Shear walls were provided at all corners in L shape. The comparison has been done by considering the parameters such as storey displacement and storey drift. It has been concluded that displacement and drift in J shape is more so need to be analyzed to minimize the wind load and rectangular structure in wind prone zone is preferred.

Naveen. G.M *et al*. (2016) [2] carried out seismic analysis of 10 storey RC frame building with regular and irregular plan shape by response spectrum method using ETABS 2015 and IS Code 1893:2002 (part 1). Three models with one regular andtwo irregular were considered for study. All models have different shape but having same area. The comparison has been done by considering the parameters such as maximum storey

displacement, storey drift, storey stiffness, periods and frequencies of modes during earthquake. It has been concluded that irregular shape building has the higher frequency.

Storey drift is maximum in regular shape building as compared to irregular buildings. If the buildings are having greater length in the direction of earthquake motion, then are affected more. Storey shear in the irregular building structure is higher as compared to regular structure.

Ramesh Konakalla *et al*. (2014) [3] carried out the seismic and wind analysis of 20 storey building with different plan shapes like square, L, inverted U and T shape by using linear static analysis and STAAD Pro software.

For linear static analysis IS 1893 (part-1):2002 was used and for wind analysisASCE-7: 02 code was used. The comparison has been done in terms of storey drift and lateral displacement. It has been concluded that in the regular frame, there is no torsional effect in the frame because of symmetry. In case of irregular structure responses are different for the columns located in the plane perpendicular to the force action. For U plan 20 shape the responses in the corner columns of two limbs are same in the earthquake loads but different in wind loads.

Veena S. Ravi *et al*. (2016) [4] carried out the seismic analysis of G+11 storey building for zone II and V having seven different plan shapes with one regular plan and remaining irregular plan i.e., C, E, H, L, T, PLUS shapes with the help of STAAD-PRO software and IS-1893 2002-Part-1. Response spectrum analysis method was used for analysis. The comparison has been done by considering the parameters such as design lateral shear, time period, joint displacement. It has been concluded that regular square plan building has maximum base shear value whereas L shape building have the least value zone II and V. Frequency and displacement is maximum in L shaped building. Irregular shaped buildings undergo maximum displacement than regular buildings during earthquake.

Pradeep Pujar *et al*. (2017) [5] analysed G+9 storied irregular buildings to find their seismic performance with and without shear walls. Shapes of building plan considered for the study were I, L and C. Three models of bare frame and three models with shear walls were considered for the study. The models have been analyzed by Equivalent static technique with the assistance of E-tabs V 15.0.0 programming. The comparison has been done by considering the parameters such as story displacement, story drift and base shear. It has been concluded that L-shape, C-shape structures with Shear walls are having great outcomes in base shear, story drift and displacement. In all shapes the I-shape building with shear wall is having increased base shear both in X and Y direction and the L-shape is having very less increased base shear. The building with shear wall gives better execution against the seismic tremor when compared with bare frame building.

Jereen Ann Thomas *et al*. (2016) [6] carried out the seismic analysis of 12 storied building with E, H, plus and swastika shape plan using ETABS v9 software and IS 1893(part1):2002. Comparative study of structure with rigid and semi rigid diaphragm was considered. The comparison has been done by considering the parameters such as base shear, displacement and storey drift, torsional buckling. It has been concluded that plan configuration of the structure affects the displacement and storey drift. The swastika shape configuration showed good performance compared to the other models. For the structures with plan irregularity semi rigid diaphragm must be considered.

Mangesh S. Suravase *et al.* (2017) [7] performed seismic analysis on G+10 storied R.C frame buildings with different plan shapes such as square, H-shape, L-shapeand rectangle with core. Plan area and height of all building models were kept same. Seismic analysis was carried out by pushover analysis method in ETABS software. The comparison has been done by considering the parameters such as base force and monitored displacement. It has been concluded that the regular building resist earthquake forces longer time and withstand for longer time. Irregular building model shape-H and L is having less resistance to earth quake forces. Irregular building model shape-O is having more resistance to earthquake than H and L shape building.

M. R. Wakchaure *et al*. (2012) [8] carried out seismic and wind analysis of35 and 39 storied buildings having dual systems and plan irregular shapes like T and oval shape by using ETABS software and IS:1893(Part-1)-2002. The comparison has been done by considering the parameters such as time period, frequency modal mass participating ratios and displacement. It has been concluded that dual system is better solution to

overcome the effects produced by plan irregularities. G. Guruprasad *et al*. (2017) [9] performed a dynamic analysis of G+15 storied RC frame building with L, C and rectangular shape in plan with the help of ETABS software. Comparison has been done by considering the parameters such as story drift, story shear, support reactions, building mode, and section cut force. It has been concluded that maximum value of story shear was observed for L-shape plan than rectangular building and C-shape building. The stories drift values in X direction and Y direction increases for top to bottom story in all three cases. When earthquake load is applied in Y direction, it was found that irregular plan structure can resist more base shear than rectangular plan structure. Regular building and L shape buildings are giving good results than C-shaped buildings in all aspect.

Further, Narla Mohan *et al*. (2017) [10] performed seismic analysis and wind analysis on G+20 storey RC building square in shape with four different zones II, III, IV and V. The analysis was carried out by adopting using ETAB software adopting response spectrum analysis method and wind analysis as per IS 875-1987 part-III using ETABS software. Four models were used to analyze with different bay lengths. Different values of seismic zone factor were taken and their corresponding effects were interpreted in the results. The comparison has been done by considering the parameters such as storey drift, storey shear, torsional force and displacement. It has been concluded that the base shear and displacement of structure increases as we go to higher seismic zones. The storey drift due to wind load is mainly occurred at the middle of the 22-building structure. Storey Shear is decreased as height of the building increased and reduced at top floor in all the building models. Least stable of all the shapes. Plus, shape and Non uniform are the most stable.

III. OBJECTIVES OF THE STUDY

The main objective of this study is to model high-rise buildings using ETABS software and investigate their behaviour when subjected to wind and earthquake forces. The study aims to compare buildings with different plan shapes while maintaining the same floor area to evaluate the influence of plan geometry on structural response. It also seeks to determine the effects of wind and earthquake forces on various structural parameters and to identify the most efficient plan shape for high-rise buildings through comparative analysis. Furthermore, the study focuses on analyzing the effects of different plan shapes on the structural behaviour of buildings under earthquake loading. force and Wind force.

IV. METHOD OF ANALYSIS

1. Wind Analysis:

Wind analysis is carried out using ETABS 2018 software to evaluate the behaviour of high-rise buildings subjected to wind loads.

2. Response Spectrum Analysis:

Response Spectrum Analysis is used to evaluate the dynamic behaviour of high-rise buildings under earthquake loading, considering their natural frequencies and mode shapes. The method uses response spectra representing the maximum displacement, velocity, or acceleration of a single degree of freedom (SDOF) system for different natural periods and damping ratios. The design horizontal seismic coefficient is calculated using the applicable parameters specified in IS 1893, considering the zone factor, importance factor, response reduction factor, and spectral acceleration. The response spectrum is selected according to the relevant soil conditions and structural characteristics.

V. STRUCTURAL MODELLING

The following parameters should be considered while modelling and analysing high-rise buildings using ETABS software. The study aims to evaluate the structural response of buildings with different plan shapes under wind and earthquake loading by examining story shear, fundamental time period, overall bending moment, inter storey drift, story acceleration, and story stiffness. The analysis should assess story shear and overall bending moment in relation to the applied loads and structural capacity, while lower inter storey drift is generally desirable for controlling lateral deformation.

The fundamental time period should be evaluated in relation to the building's stiffness and dynamic response rather than assuming that a longer period is always better. Similarly, story acceleration should be assessed based on structural and nonstructural response requirements, as higher acceleration is not necessarily

desirable. Story stiffness and its distribution should also be examined to understand the lateral stability and behaviour of each building configuration. These parameters will be compared for the different plan shapes to identify their relative structural performance under wind and earthquake forces.

A. Circular Shaped Building

This is the module describing circular shaped building with six discussed parameters

1. Base Shear in X and Y Direction

Base shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure.

Table 1: Base Shear in X and Y Direction for Circular Shaped Building

Story Level	Max. Vx	Max. Vy
Terrace	805.8528	1007.9183
30th	1670.4911	1911.6816
29th	2380.1926	2417.2859
28th	2908.721	2884.4356
27th	3233.8652	3212.4037
26th	3341.6083	3326.4911
25th	3228.5865	3222.444
24th	2903.2652	2907.4518
23rd	3764.1503	2400.4193
22nd	5391.2839	2263.8672
21st	6289.1846	3244.9633
20th	6202.0168	3866.6497
19th	5738.766	4649.5571
18th	5744.3566	5153.4919
17th	5085.5474	5140.1329
16th	3817.09	4561.0389
15th	2072.6789	3423.1359
14th	1689.8341	4156.5973
13th	1736.509	4516.2179
12th	1780.971	3985.4229
11th	4361.0432	2647.832
10th	9185.6649	2975.4186
9th	12547.2676	2902.0369
8th	12780.3125	2439.8127
7th	12404.5896	5209.0881
6th	12721.0822	10806.9556
5th	9426.4713	15491.6983
4th	8993.8185	17257.5046
3rd	7035.1205	17015.1369
2nd	4586.7609	10791.5099
1st	20638.5997	7304.8745
Ground	91215.5277	4166.4425

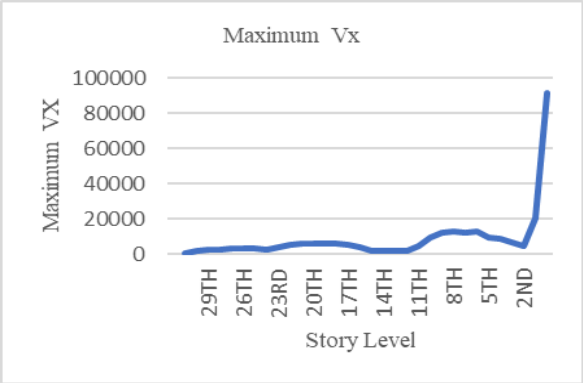


Fig 1(a): Story Level vs Max. Vx (Circular Shaped Building)

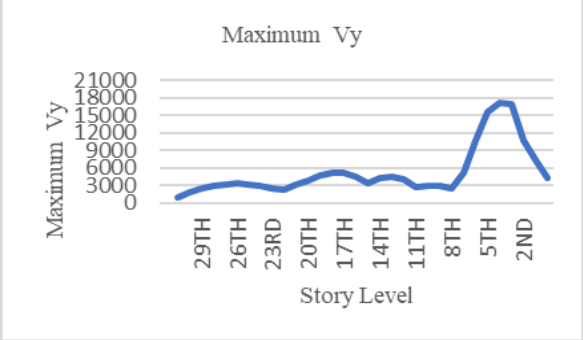


Fig 1(b): Story Level vs Max. Vy (Circular Shaped Building)

2. Time Period

The approximate fundamental natural period of vibration (Ta), in seconds

Table 2: Time Period for Circular Shaped Building

Mode	Period (sec)
1	3.309
2	3.309
3	2.383
4	1.015
5	1.015
6	0.544
7	0.544
8	0.359
9	0.35
10	0.244
11	0.183
12	0.127

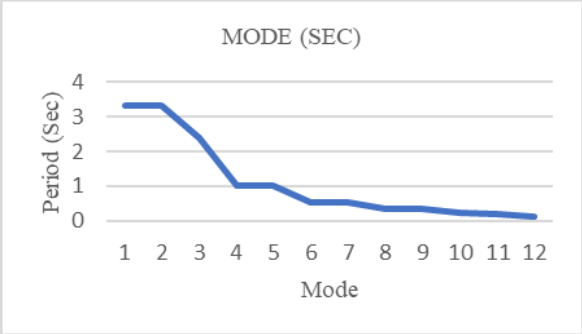


Fig 2: Mode vs Period (Circular Shaped Building)

3. Overall Moment in X and Y Direction

It is the amount of overall bending moment in X and Y direction generated by the structure as per ETABS 2018 Software referring to IS:456 and IS 1893, etc.

Table 3: Overall Moment for Circular Shaped Building

Story Level	Max. Mx	Max. My
Terrace	135330.2457	2417.5585
30th	272670.3708	7429.0317
29th	410010.504	14569.6095
28th	547350.6455	23295.7723
27th	684690.7952	32997.368
26th	822030.953	43022.193
25th	959371.119	52707.9526
24th	1096711.293	61417.7481
23rd	1234051.475	68575.9566
22nd	1371391.665	73701.8041
21st	1508731.863	76438.285
20th	1646072.069	76574.4285
19th	1783412.282	76574.4285
18th	1920752.503	74059.3195
17th	2058092.732	69006.7426
16th	2195432.968	61689.8593
15th	2332773.212	52525.9144
14th	2470113.463	42831.577
13th	2607453.721	43250.1632
12th	2744793.986	43449.1645
11th	2882134.258	46467.582
10th	3019474.537	49555.9817
9th	3156814.822	52714.2781
8th	3294155.113	56658.7797
7th	3431495.41	82093.0314
6th	3568835.712	82093.0314
5th	3706176.02	79535.1101
4th	3843516.332	69667.0593
3rd	3980856.649	73327.681
2nd	4118196.968	77090.0529
1st	4255537.29	80948.942
Ground	4378811.028	241695.962

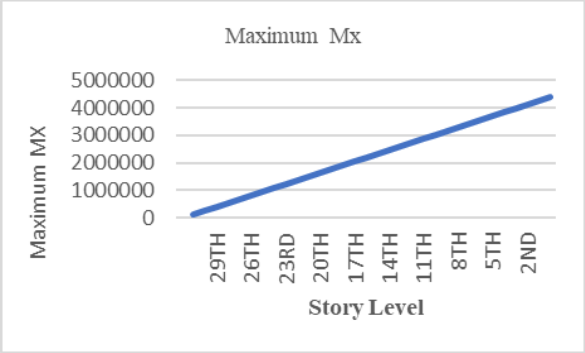


Fig 3(a): Story Level vs Max. Mx (Circular Shaped Building)

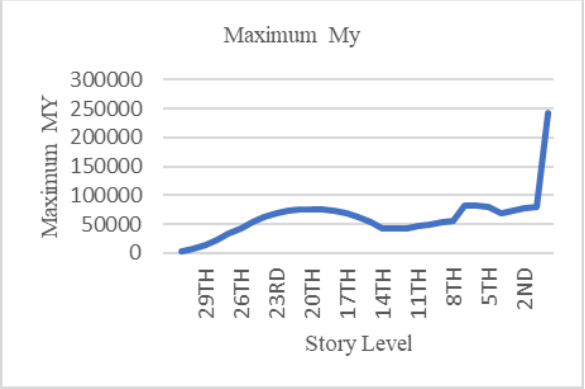


Fig 3(b): Story Level vs Max. My (Circular Shaped Building)

4. Inter Story Drift

Inter-story drift of building structures is defined as the relative translational displacement difference between two consecutive floors.

Table 4: Inter Story Drift for Circular Shaped Building

Story Level	Max. Drift
Terrace	0.002632
30th	0.000763
29th	0.000856
28th	0.000891
27th	0.000846
26th	0.000715
25th	0.000679
24th	0.000629
23rd	0.000664
22nd	0.000772
21st	0.000881
20th	0.000843
19th	0.000893

18th	0.000889
17th	0.000809
16th	0.000823
15th	0.000884
14th	0.001117
13th	0.001151
12th	0.00095
11th	0.000905
10th	0.00114
9th	0.001347
8th	0.001245
7th	0.00155
6th	0.001557
5th	0.001878
4th	0.002609
3rd	0.002403
2nd	0.001085
1st	0.001851
Ground	0.002632

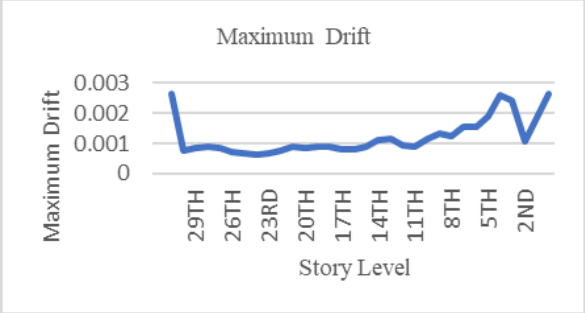


Fig 4: Story Level vs Story Drift (Circular Shaped Building)

5. Story Acceleration

Inter-story drift of building structures is defined as the relative translational displacement difference between two consecutive floors.

Table 5: Acceleration for Circular Shaped Building

Story Level	Max. Ux	Max. Uy	Max. Uz
Terrace	217.2	213.19	29.06
30th	191.6	190.39	30.83
29th	164.97	165.63	32.95
28th	140.53	141.01	34.1
27th	123.41	121.18	33.73
26th	117.3	111.85	31.87
25th	120.42	113.37	28.98
24th	127.09	121.65	26.22
23rd	132.8	130.96	23.34
22nd	136	137.43	21.77
21st	137.62	139.93	20.9
20th	139.38	139.19	19.89
19th	142.09	137.13	18.51
18th	144.73	136.29	18.23
17th	145.7	138.42	17.56
16th	144.37	142.45	19.3
15th	142.18	146.22	21.74
14th	142.12	147.75	23.33
13th	145.46	146.62	23.29
12th	150.72	144.65	22
11th	154.88	145.23	23.43
10th	156.56	151.69	23.69
9th	158.21	162.43	25.27
8th	164.48	172.26	26.29
7th	174.95	176.3	24.38
6th	181.9	173.18	25.64
5th	178.14	167.87	30.79
4th	166.94	169.92	35.79
3rd	165.07	180.53	39.42
2nd	176.16	183.43	30.48
1st	167.56	156.2	24.68
Ground	133.51	101.63	44.83

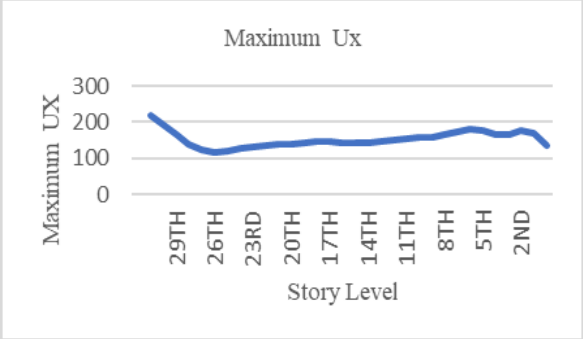


Fig 5(a): Story Level vs Max. Ux (Circular Shaped Building)

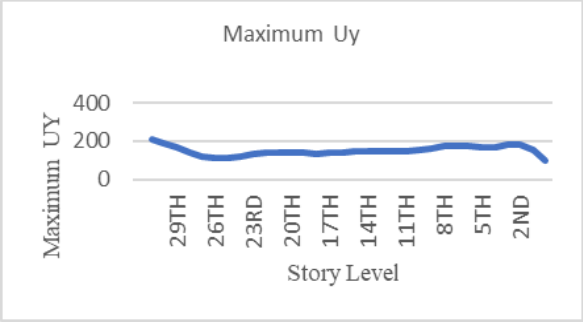


Fig 5(b): Story Level vs Max. Uy (Circular Shaped Building)

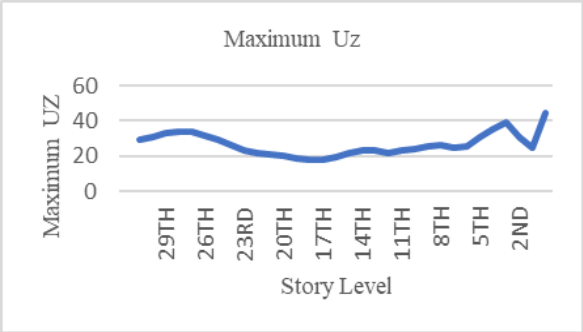


Fig 5(c): Story Level vs Max. Uz (Circular Shaped Building)

6. Story Stiffness in X and Y Direction

Story stiffness of building structures is defined as the lateral force producing unit translational lateral deformation in that storey, with the bottom of the storey restrained from moving laterally, i.e., only translational motion of the bottom of the storey is restrained while it is free to rotate.

Table 6: Story Stiffness for Circular Shaped Building

Story Level	Max. Stiff X	Max. Stiff Y
Terrace	922821.073	918858.037
30th	1566443.503	1566506.631
29th	757592.174	742845.881
28th	868567.584	857109.484
27th	933394.423	926413.739
26th	969210.142	966307.389
25th	988152.888	987942.015
24th	998730.851	999237.028
23rd	1006766.307	1006121.12
22nd	1015732.219	1012939.742
21st	1026995.066	1022368.535
20th	1040378.763	1035322.144
19th	1055013.952	1051217.372
18th	1070124.852	1068627.33
17th	1085441.924	1086071.793
16th	1101132.258	1102630.728
15th	1117455.647	1118218.134
14th	1134438.832	1133498.489
13th	1151844.556	1149520.918
12th	1169485.107	1167224.141
11th	1187673.352	1187041.862
10th	1207425.521	1208859.551
9th	1230175.711	1232458.057
8th	1257199.519	1258348.853
7th	1289505.378	1288667.767
6th	1328967.734	1327651.493
5th	1380654.847	1381492.651
4th	1455093.555	1458521.391
3rd	1570851.369	1573369.286
2nd	1767341.154	1766008.013
1st	2176200.533	2180974.45
Ground	7244078.761	7195108.306

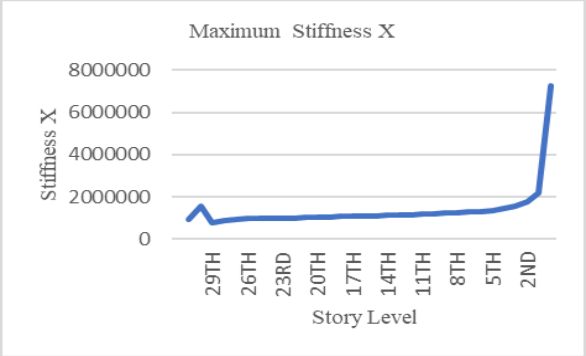


Fig 6(a): Story Level vs Stiff. X (Circular Shaped Building)

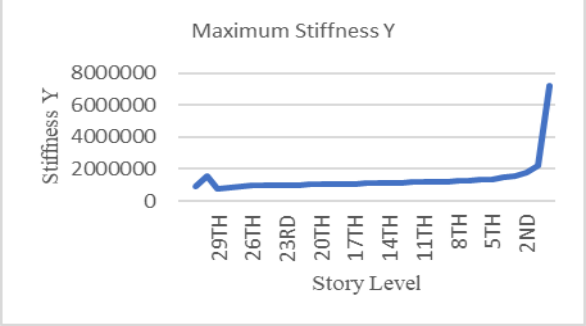


Fig 6(b): Story Level vs Stiff. Y (Circular Shaped Building)

B. C-Shaped Building

This is the module describing C shaped building with six discussed parameters

1. Base Shear in X and Y Direction

Base shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure.

Table 7: Base Shear in X and Y Direction for C Shaped Building

Story Level	Max. Vx	Max. Vy
Terrace	1681.4038	180.8213
30th	338.2877	299.6233
29th	3166.5082	385.3668
28th	638.1038	637.9796
27th	4017.9268	574.5567

26th	954.4342	763.8376
25th	1017.9348	954.797
24th	4161.3535	745.6557
23rd	1281.17	1250.803
22nd	3588.0105	984.6145
21st	1554.7203	1526.7225
20th	2375.8329	1192.9695
19th	1867.4024	1783.2792
18th	1657.6564	1783.2792
17th	2178.4598	1022.2995
16th	2021.2716	2021.196
15th	1988.8283	1533.4492
14th	2487.8904	2241.1954
13th	3103.557	1664.5477
12th	2795.6912	2443.9995
11th	1990.269	1771.4692
10th	3809.1114	2104.2645
9th	2630.0971	2630.3306
8th	3825.121	1286.2712
7th	3406.3865	2800.9105
6th	4469.0106	1929.4068
5th	3709.2702	2956.4613
4th	5088.1793	1992.8864
3rd	4010.5021	2478.1637
2nd	3096.9507	3097.7046
1st	5142.3618	1930.8541
Ground	4310.0738	3225.3621

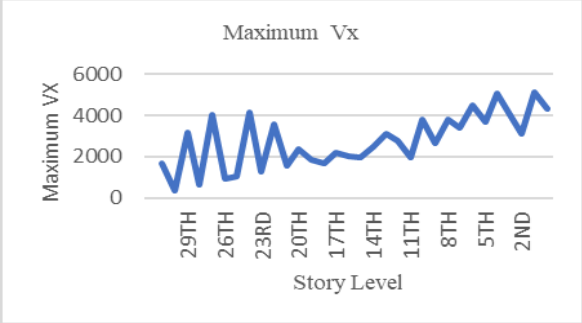


Fig 7(a): Story Level vs Max. Vx (C Shaped Building)

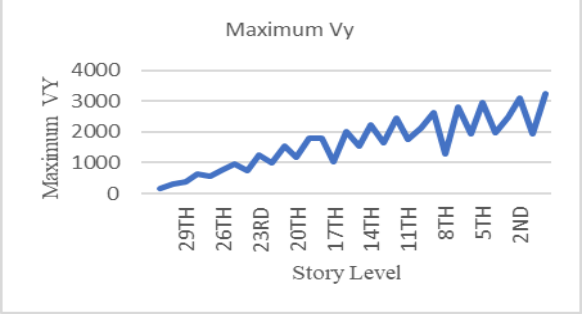


Fig 7(b): Story Level vs Max. Vy (C Shaped Building)

2. Time Period

The approximate fundamental natural period of vibration (Ta), in seconds

Table 8: Time Period for C Shaped Building

Mode	Period (Sec)
1	3.641
2	3.565
3	2.663
4	1.132
5	1.101
6	0.85
7	0.596
8	0.596
9	0.398
10	0.3
11	0.272
12	0.142

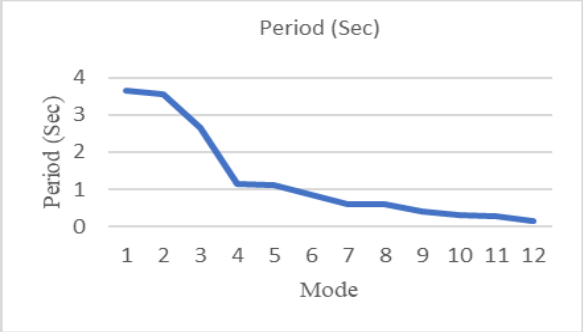


Fig 8: Mode vs Period (C Shaped Building)

3. Overall Moment in X and Y Direction

It is the amount of overall bending moment in X and Y direction generated by the structure as per ETABS 2018 Software referring to IS:456 and IS 1893, etc.

Table 9: Overall Moment for C Shaped Building

Story Level	Max. Mx	Max. My
Terrace	185804.3243	5044.2114
30th	168271.1944	-28604.2213
29th	249236.6992	14543.7359
28th	373855.0487	-70696.0537
27th	339202.1223	26597.5162
26th	561905.7731	4117.6423
25th	511080.9315	660.6082
24th	749956.4975	39081.5767
23rd	685658.1068	-151405.0312
22nd	938007.2219	49845.6081
21st	859856.9987	-191136.6438

20th	856846.2389	56973.1067
19th	1126057.946	12918.7568
18th	1030585.673	1868.7107
17th	1314108.671	59049.3764
16th	1210507.874	-267187.5532
15th	1502159.395	59049.3764
14th	1386850.184	-303560.0652
13th	1379366.383	55389.0774
12th	1690210.119	23811.0208
11th	1554238.688	3643.7367
10th	1878260.844	46182.8113
9th	1741310.624	-376041.1904
8th	2066311.568	32532.1721
7th	1919332.08	-407376.4503
6th	1904562.327	35573.1324
5th	2254362.293	-440148.1922
4th	2079892.865	16565.9647
3rd	2442413.017	39665.0263
2nd	2255282.748	6804.6667
1st	2630463.741	43851.2401
Ground	2456026.837	-502970.678

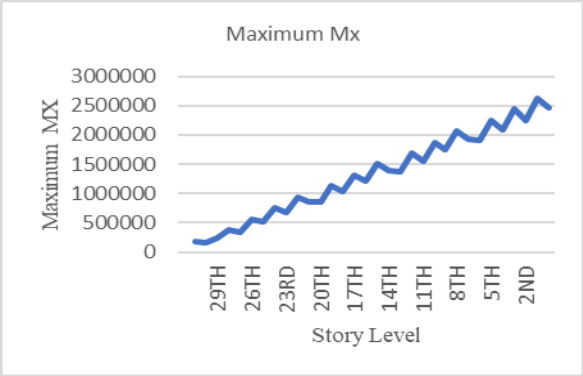


Fig 9(a): Story Level vs Max. Mx (C Shaped Building)

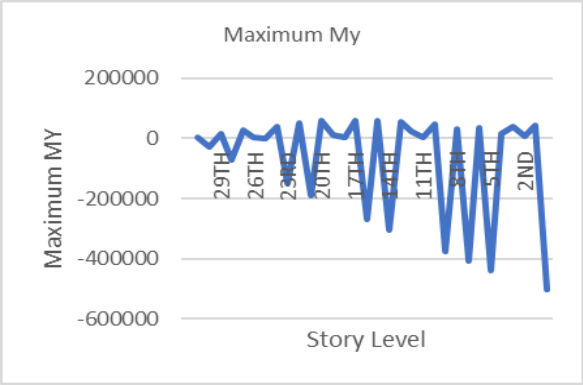


Fig 9(b): Story Level vs Max. My (C Shaped Building)

4. Inter Story Drift

Inter-story drift of building structures is defined as the relative translational displacement difference between two consecutive floors.

Table 10: Inter Story Drift for C Shaped Building

Story Level	Max. Mx
Terrace	0.003606
30th	0.000876
29th	0.000854
28th	0.00099
27th	0.000912
26th	0.001041
25th	0.000985
24th	0.001065
23rd	0.001065
22nd	0.001148
21st	0.001036
20th	0.001234
19th	0.000795
18th	0.001319
17th	0.000895
16th	0.001404
15th	0.001487
14th	0.001463
13th	0.00157
12th	0.001319
11th	0.001652
10th	0.001112
9th	0.001731
8th	0.001452
7th	0.001809
6th	0.001885
5th	0.001782
4th	0.001959
3rd	0.001491
2nd	0.00203
1st	0.001325
Ground	0.002099

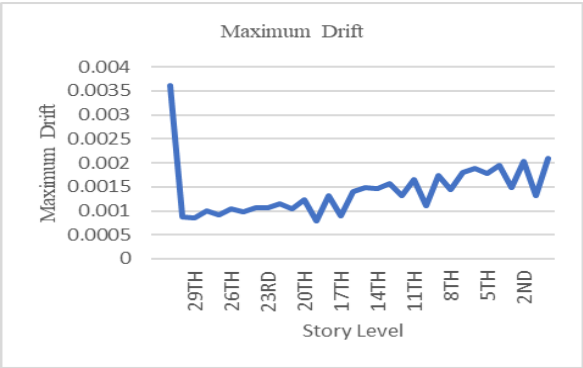


Fig 10: Story Level vs Story Drift (C Shaped Building)

5. Story Acceleration

Inter-story drift of building structures is defined as the relative translational displacement difference between two consecutive floors.

Table 11: Acceleration for C Shaped Building

Story Level	Max. Ux	Max. Uy	Max. Uz
Terrace	390.44	369.21	33.37
30th	339.88	338.85	33.22
29th	288.44	305.1	32.9
28th	243.35	268.47	32.35
27th	216.66	232.37	31.55
26th	214.24	203.07	30.51
25th	227.22	188.4	29.24
24th	241.18	192.75	27.81
23rd	247.71	212.3	26.27
22nd	246.68	238.21	24.7
21st	244	262.39	23.15
20th	246.66	279.35	21.67
19th	256.44	286.12	20.31
18th	268.03	282.07	19.09
17th	273.92	269.13	18.02
16th	270.5	252.22	17.3
15th	261.39	239.27	19.53
14th	256.43	238.9	21.28
13th	263.73	254.65	21.3
12th	280.24	281.54	19.78
11th	294.17	309.71	18.94
10th	297.28	329.75	21.42
9th	294.19	335.95	26.01
8th	300.91	328.49	28.93
7th	325.2	315.81	27.63
6th	349.54	314.08	23.93
5th	348.49	335.8	26.81
4th	323.49	375.96	37.81
3rd	324.01	403.49	44.22
2nd	374	381.81	35.57
1st	383.69	297.65	23.69
Ground	386.89	194.92	52.18

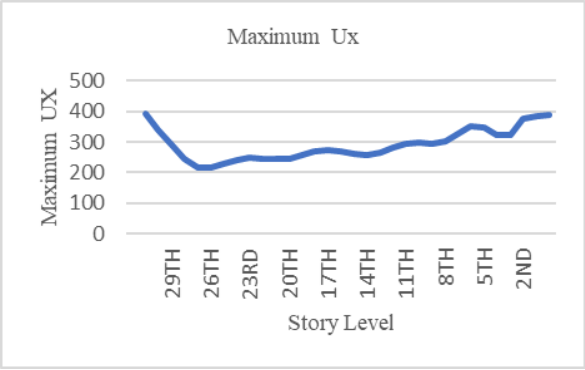


Fig 11(a): Story Level vs Max. Ux (C Shaped Building)

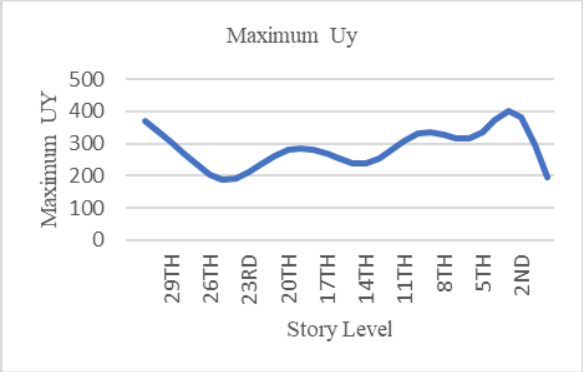


Fig 11(b): Story Level vs Max. Uy (C Shaped Building)

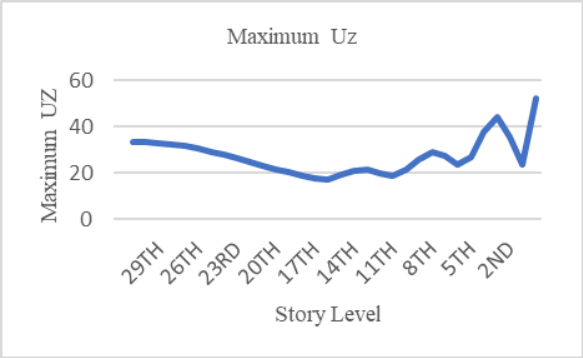


Fig 11(c): Story Level vs Max. Uz (C Shaped Building)

6. Story Stiffness in X and Y Direction

Story stiffness of building structures is defined as the lateral force producing unit translational lateral deformation in that storey, with the bottom of the storey restrained from moving laterally, i.e., only translational motion of the bottom of the storey is restrained while it is free to rotate.

Table 12: Story stiffness for C Shaped Building

Story Level	Max. Stiff. X	Max. Stiff. Y
Terrace	263624.36	246156.328
30th	494947.311	460864.285
29th	641075.161	600280.785
28th	726976.53	687292.718
27th	775029.518	742003.673
26th	800516.693	776552.148
25th	813739.379	798127.278
24th	821757.792	811062.038
23rd	829126.634	818164.173
22nd	838099.123	831779.553
21st	848978.846	844248.505
20th	860917.294	855013.385

19th	872914.523	864545.478
18th	884558.533	873192.656
17th	896204.834	881222.604
16th	908602.084	888851.806
15th	922247.037	896261.664
14th	936922.202	903616.892
13th	951788.691	911075.049
12th	966038.606	918805.395
11th	979694.596	927009.565
10th	993947.468	935954.675
9th	1010599.26	946029.141
8th	1030852.178	957840.063
7th	1054667.316	972390.36
6th	1082104.033	991434.305
5th	1116528.844	1018211.283
4th	1167301.976	1061942.628
3rd	1250072.918	1131288.917
2nd	1393460.364	1256291.801
1st	1694942.598	1579640.279
Ground	2521393.814	2506220.616

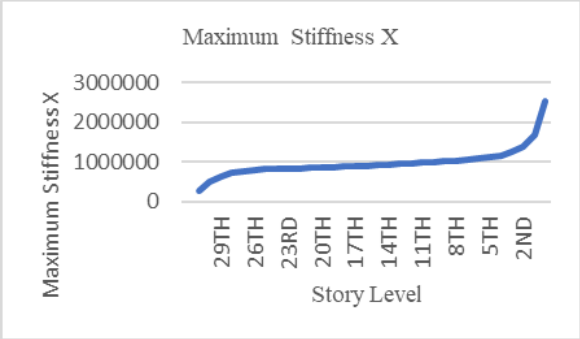


Fig 12(a): Story Level vs Stiff. X (C Shaped Building)

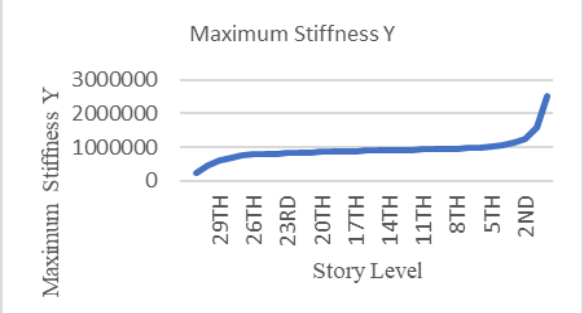


Fig 12(b): Story Level vs Stiff. X (C Shaped Building)

C. Hollow Rectangular Shaped Building

This is the module describing hollow rectangular shaped building with six discussed parameters

1. Base Shear in X and Y Direction

Base shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure.

Table 13: Base Shear in X and Y Direction for Hollow Rectangular Shaped Building

Story Level	Max. Vx	Max. Vy
Terrace	1423.7164	171.8575
30th	424.5279	355.1598
29th	2507.4845	366.1528
28th	754.4169	760.8585
27th	2906.54	549.2292
26th	1131.4551	913.279
25th	1223.3398	1141.5988
24th	2626.549	707.9302
23rd	1506.0446	1498.2278
22nd	2015.4638	1061.8952
21st	1813.6854	1831.5853
20th	2055.4718	1280.4618
19th	2120.5567	2142.5059
18th	1884.6292	2142.5059
17th	2242.3832	1094.1917
16th	2405.7132	2431.8199
15th	2050.3157	1641.2876
14th	2669.9885	2700.3546
13th	3321.7029	1787.2427
12th	2914.2147	2948.9349
11th	2275.3836	1915.3164
10th	4392.916	2542.7068
9th	3139.2226	3178.3835
8th	4793.4234	1427.12
7th	3511.156	3389.5214
6th	4399.6889	2140.6799
5th	3824.5552	3583.1678
4th	3966.3028	2250.1706
3rd	4136.397	3008.1123
2nd	3703.0904	3760.1404
1st	4446.6558	1688.3357
Ground	4442.2333	3921.2545

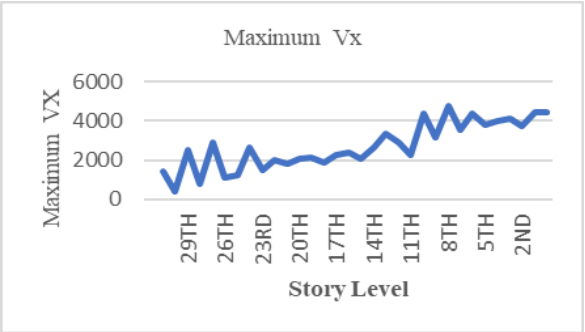


Fig 13(a): Story Level vs Max. Vx (Hollow Rectangular Shaped Building

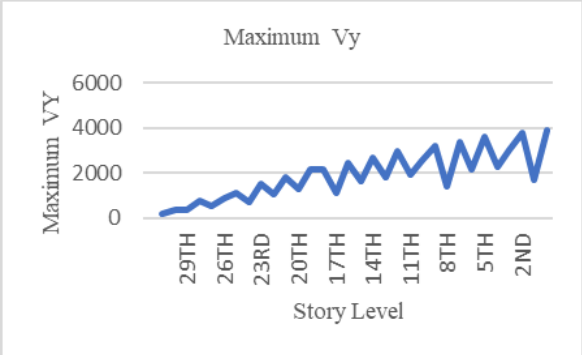


Fig 11(b): Story Level vs Max. Vy (Hollow Rectangular Shaped Building)

2. Time Period

The approximate fundamental natural period of vibration (Ta), in seconds

Table 14: Time Period for C Shaped Building

Mode	Period (sec)
1	5.257
2	4.566
3	3.997
4	1.561
5	1.374
6	1.229
7	0.809
8	0.73
9	0.467
10	0.392
11	0.308
12	0.168

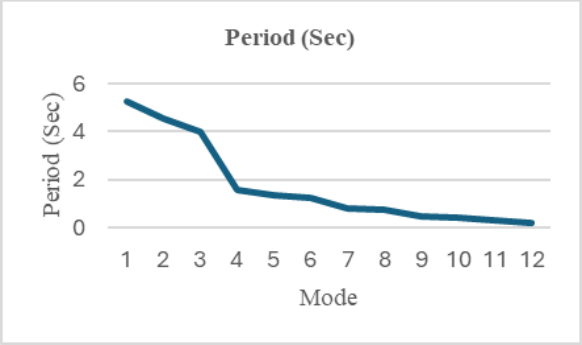


Fig 14: Mode vs Period (Hollow Rectangular Shaped Building)

3. Overall Moment in X and Y Direction

It is the amount of overall bending moment in X and Y direction generated by the structure as per ETABS 2018 Software referring to IS:456 and IS 1893, etc.

Table 15: Overall Moment for Hollow Rectangular Shaped Building

Story Level	Max. Mx	Max. My
Terrace	215845.2002	4271.1491
30th	195406.6795	-48522.6189
29th	290174.4003	11793.6026
28th	435261.6005	-122600.4054
27th	394674.4048	20513.2227
26th	654678.0007	5007.0102
25th	595039.0209	439.1504
24th	874094.4009	28392.8698
23rd	799345.9353	-266404.9034
22nd	1093510.801	33638.6532
21st	1002753.091	-337900.3401
20th	997879.4248	34953.2959
19th	1312927.201	15055.8209
18th	1200194.012	1246.6805
17th	1532343.602	34953.2959
16th	1412300.869	-476376.2468
15th	1751760.002	38200.0888
14th	1618314.333	-544299.8972
13th	1606208.27	42359.4487
12th	1971176.402	27025.9745
11th	1809761.638	45214.8721
10th	2190592.802	31280.9151
9th	2032521.089	-677831.7277
8th	2410009.203	46572.6114
7th	2240602.053	-743557.6721
6th	2217679.859	46572.6114
5th	2629425.603	-808664.6581
4th	2421978.964	46333.1547
3rd	2848842.003	45056.294
2nd	2626489.568	4568.115
1st	3068258.403	50019.629
Ground	2868132.942	-937229.8882

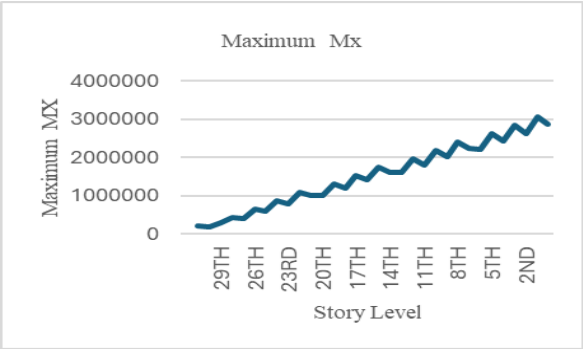


Fig 15(a): Story Level vs Max. Mx (Hollow Rectangular Shaped Building)

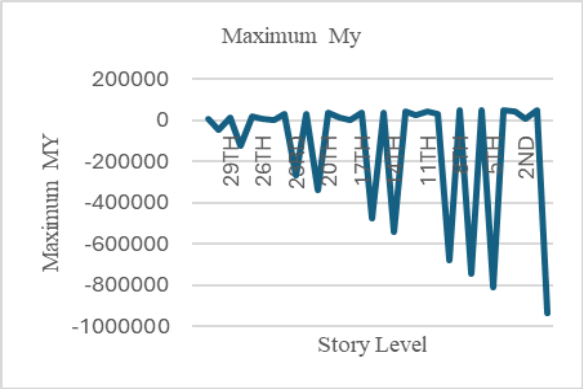


Fig 15(b): Story Level vs Max. My (Hollow Rectangular Shaped Building)

4. Inter Story Drift

Inter-story drift of building structures is defined as the relative translational displacement difference between two consecutive floors.

Table 16: Inter Story Drift for Hollow Rectangular Shaped Building

Story Level	Max. Drift
Terrace	0.003178
30th	0.001039
29th	0.001166
28th	00.001008
27th	0.001273
26th	0.00107
25th	0.001392
24th	0.001431
23rd	0.001519
22nd	0.001658
21st	0.001209
20th	0.001813
19th	0.001891
18th	0.001964
17th	0.00211
16th	0.002081
15th	0.002248
14th	0.002377
13th	0.002377
12th	0.002497
11th	0.002473
10th	0.002608
9th	0.002708
8th	0.001865
7th	0.002798
6th	0.002844
5th	0.002878
4th	0.002961
3rd	0.00208
2nd	0.003072
1st	0.003178
Ground	0.003052

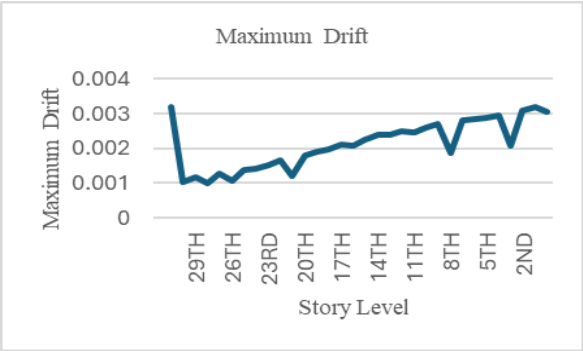


Fig 16: Story Level vs Story Drift (Hollow Rectangular Shaped Building)

5. Story Acceleration

Inter-story drift of building structures is defined as the relative translational displacement difference between two consecutive floors.

Table 17: Acceleration for Hollow Rectangular Shaped Building

Story Level	Max. Ux	Max. Uy	Max. Uz
Terrace	429.11	325.87	26.61
30th	350.25	285.21	27.38
29th	279.62	244.65	28.26
28th	230.68	206.95	28.01
27th	219.2	178.1	26.25
26th	237.36	165.62	23.17
25th	260.8	172.31	19.56
24th	272.77	191.98	18.44
23rd	269.63	214.84	17.29
22nd	258.1	233.12	16.17
21st	250.56	242.12	15.67
20th	255.77	239.83	15.5
19th	270.34	226.9	14.15
18th	282.73	207.12	12.92
17th	284.07	188.24	13.62
16th	274.66	181.07	16.8
15th	264.6	192.93	19.49
14th	266.74	219.83	20.41
13th	282.67	250.36	19.34
12th	299.52	273.45	17.44
11th	303.61	281.46	17.14
10th	294.01	271.28	19.46
9th	287.08	246.4	22.39

8th	302.67	220.94	23.35
7th	334.9	220.2	26.09
6th	355.6	270.06	25.89
5th	348.33	334.99	24.45
4th	333.99	380.95	30.97
3rd	356.76	387.74	30.93
2nd	396.55	342.58	21.28
1st	368.51	245.6	26.36
Ground	747.69	126.52	35.61

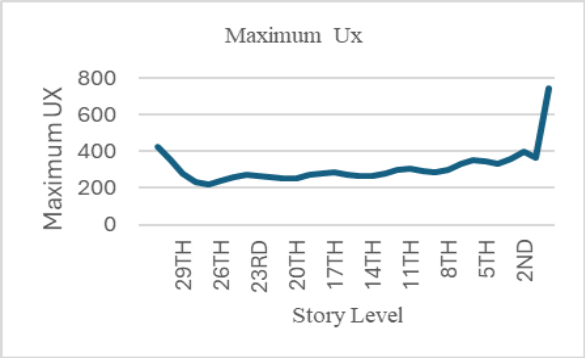


Fig 17(a): Story Level vs Max. Ux (Hollow Rectangular Shaped Building)

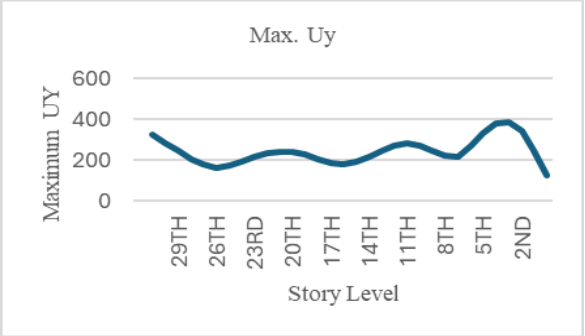


Fig 17(b): Story Level vs Max. Uy (Hollow Rectangular Shaped Building)

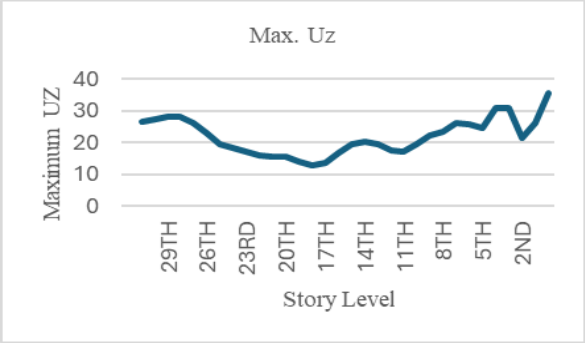


Fig 17(c): Story Level vs Max. Uz (Hollow Rectangular Shaped Building)

6. Story Stiffness in X and Y Direction

Story stiffness of building structures is defined as the lateral force producing unit translational lateral deformation in that storey, with the bottom of the storey restrained from moving laterally, i.e., only translational motion of the bottom of the storey is restrained while it is free to rotate.

Table 18: Story stiffness for Hollow Rectangular Shaped Building

Story Level	Max. Stiff. X	Max. Stiff. Y
Terrace	207518.46	132826.165
30th	391787.794	259869.267
29th	505343.796	348400.704
28th	566429.261	406104.181
27th	594646.397	441861.684
26th	604979.812	462987.768
25th	607783.071	474567.546
24th	609767.313	480039.249
23rd	614114.97	481834.964
22nd	620948.893	481778.39
21st	628647.442	481282.495
20th	635453.566	481399.898
19th	640599.395	483764.959
18th	644579.234	485901.903
17th	648656.266	489791.826
16th	653963.856	494706.107
15th	660754.374	499755.854
14th	668312.06	504379.306
13th	675616.288	508285.515
12th	682290.92	511627.084
11th	689143.363	515120.241
10th	697812.578	520050.978
9th	709675.483	528087.568
8th	725009.491	540885.362
7th	743687.288	559657.675
6th	767610.121	585114.754
5th	803193.417	618343.087
4th	861262.994	663587.734
3rd	955297.884	735423.823
2nd	1112010.942	878607.803
1st	1399808.633	1235274.251
Ground	2381008.75	2227443.784

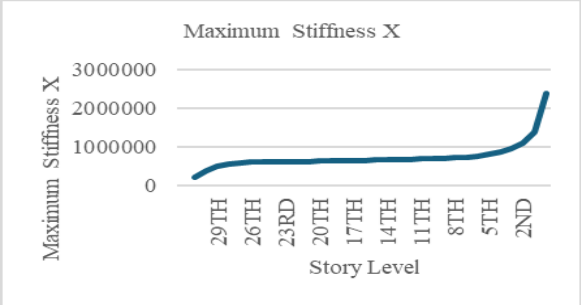


Fig 18(a): Story Level vs Stiff. X (Hollow Rectangular Shaped Building)

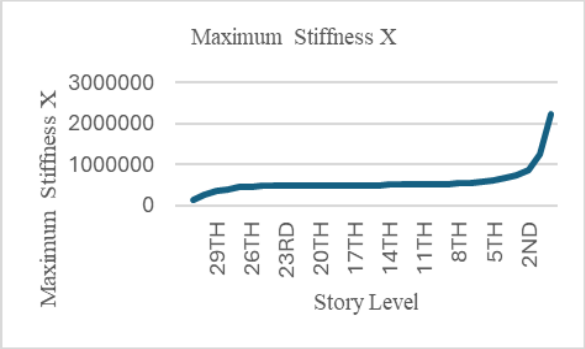


Fig 18(b): Story Level vs Stiff. Y (Hollow Rectangular Shaped Building)

VI CONCLUSION

Based on the comparative analysis of high-rise buildings with circular, hollow rectangular, and C shaped plans,

The following conclusions are drawn:

- The comparative analysis of high-rise buildings with circular, hollow rectangular, and C-shaped plans indicates that structural behaviour varies depending on the plan configuration and the parameter considered. Based on the reported base shear values, the hollow rectangular shaped building ranks first with the lowest value, followed by the C-shaped and circular-shaped buildings.
- The fundamental time period is highest for the hollow rectangular shaped building, followed by the C-shaped and circular shaped buildings. In terms of overall moment, the circular shaped building shows the lowest reported value, followed by the C shaped and hollow rectangular shaped buildings.
- The story drift results indicate that the circular-shaped building has the lowest reported drift, followed by the hollow rectangular shaped and C shaped buildings. The reported story acceleration ranking places the hollow rectangular-shaped building first, followed by the C shaped and circular shaped buildings; however, this result should be verified against the original ETABS output to confirm that acceleration, rather than displacement, has been reported. Regarding story stiffness, the circular shaped building ranks highest, followed by the C shaped and hollow rectangular shaped buildings.

Overall, the results demonstrate that no single plan configuration ranks best across all the parameters considered. The hollow rectangular-shaped building performs favourably in terms of the reported base shear and time period, whereas the circular-shaped building shows favourable results for overall moment, story drift, and story stiffness.

Therefore, selecting an appropriate plan shape for a high-rise building requires a comprehensive assessment of its response to wind and earthquake loading. The reported rankings should be verified against the ETABS results, and the final selection should also consider applicable design-code requirements, structural capacity, torsional behaviour, and serviceability limits.

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