A comparative study of unsymmetric L, C and Z-shapes structure under seismic zone 3, 4 and 5

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Abstract- In recent times, rapid urbanization has led to increasing scarcity of land and demand for symmetric and unsymmetric multistorey structure has grown simultaneously. In past two decades, it was observed that unsymmetrical structures are the most vulnerable under the effects of seismic loading due to irregularity in plan area, uneven distribution of mass & stiffness. Therefore, it is mandatory to consider the effects of lateral load induced due to earthquake in such unsymmetric multistorey structure and study their behaviour of responses.

Hence the focus of this research is to study SSI for G+10 L, C, & Z type unsymmetric multistorey structure under seismic zone 3, 4, & 5. The plan area for all unsymmetric multistorey structure is same i.e 1000m^2. With the help of response spectrum method (linear dynamic analysis), estimation of storey drift, storey shear, storey displacement and base shear is analysed by using CSI ETABS software.

INTRODUCTION

Three, midrise G+9 i.e., 30m high unsymmetrical structures, (C, L, and Z) type buildings with planar asymmetry are modelled in CSI ETABS for seismic zones 3, 4, and 5. All unsymmetrical structures have the same plan area, which is 1000 m2, and column spacing is 5 m. The equivalent static method and the response spectrum method are used to conduct the analysis. The dimensions of the beam, column, and slab thickness are 350mm x 450mm, 500mm x 500mm, and 125mm, respectively. The concrete and rebar grades used are M-30 and Fe-500, respectively. The earthquake load is applied in accordance with IS 1893:2016, considering Zones 3, 4, and 5, the importance factor for structure is 1, and the response factor is 1. The damping ratio for all models is taken as 5%. The basic parameter required for analysis are assumed and are tabulated in Table 1 while the parameters of building configuration are tabulated in Table 2.

Table 1 General Design Parameters

Serial Number	Specifications	Details
1	Type of structure	L-Shape, C-Shape and Z-Shape in building plan
2	Number of stories	G+10
3	Seismic zone	3,4,5
4	Importance factor	1
5	Response reduction factor	5
6	Soil Condition	Medium
7	Grade of Concrete	M- 30
8	Grade of Steel	Fe-500

Table 2 Building Configuration

Building Configuration	Parameters
Floor to Floor height	3m
Beam Size	350mm*450mm
Column Size	500mm*500mm
Slab Thickness	125mm
Live Load	3kN/m2
Live Load on Terrace	1.5kN/m2
Floor Finish	1.2kN/m2
Floor Finish on Terrace	1.5kN/m2
Footing Thickness	1000mm

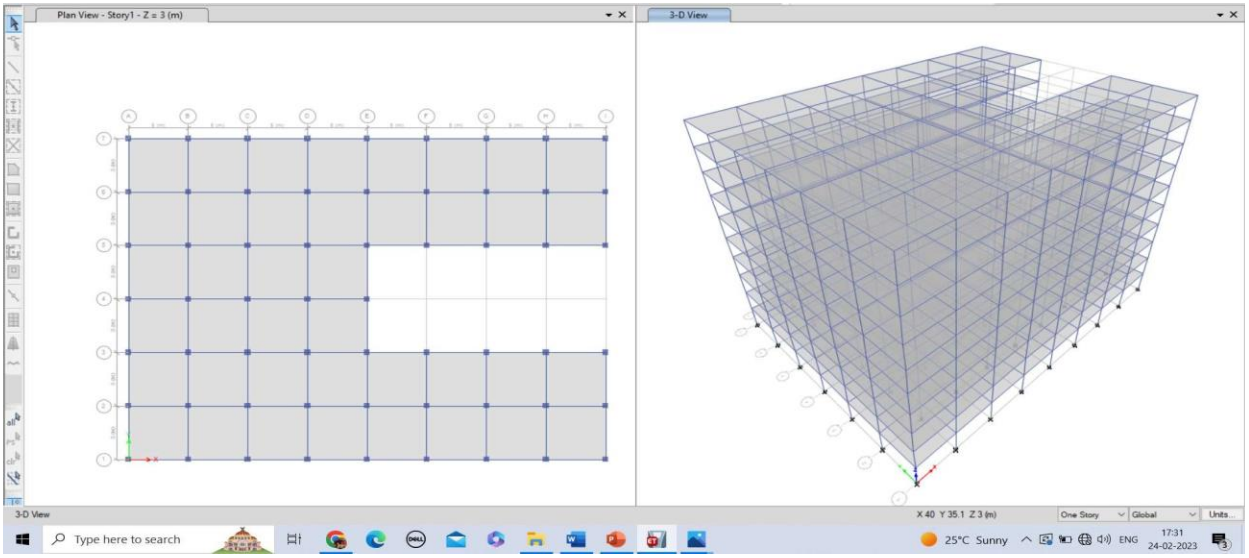

Fig 1 CSI ETABS model for C-shape building

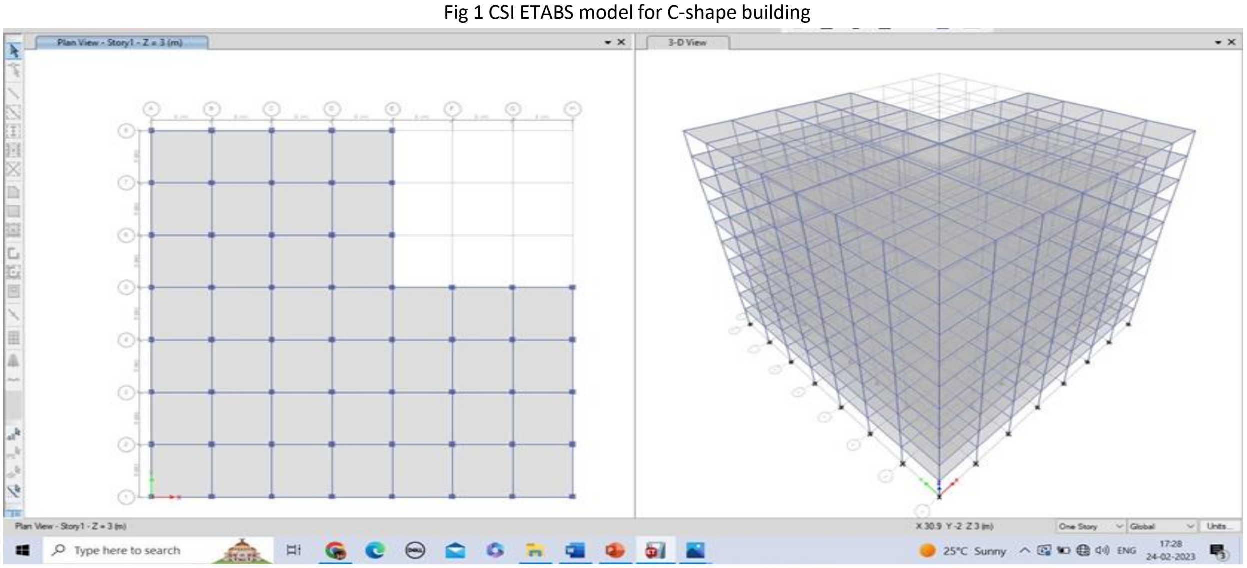

Fig. 2 CSI ETABS model for -L shape building

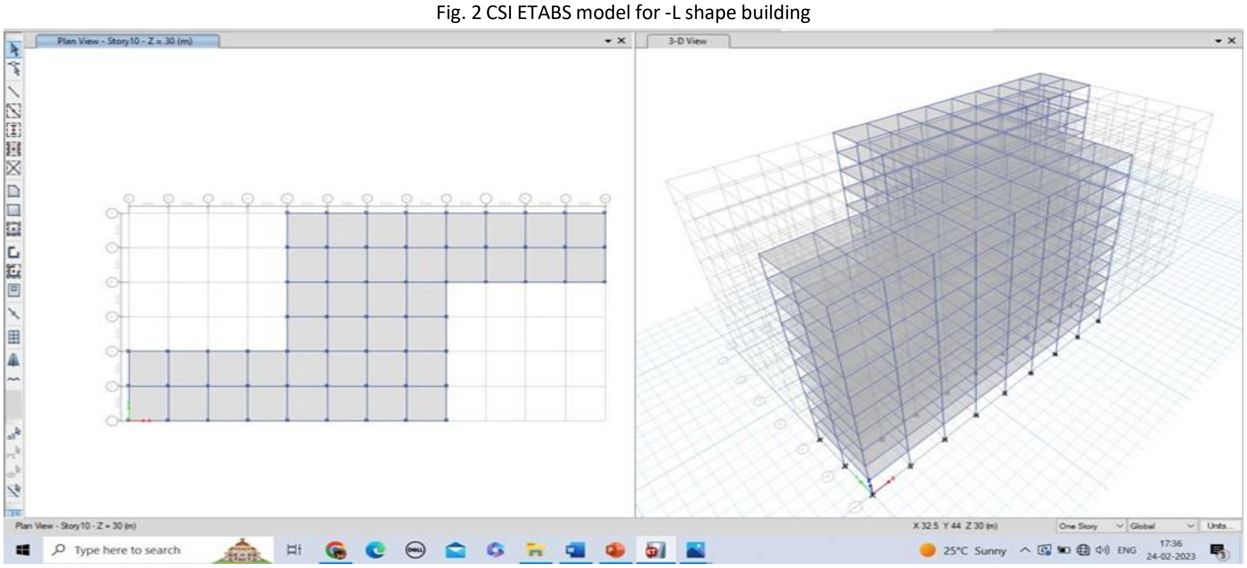

Fig. 3 CSI ETABS model for Z-shape building

Parameters obtained using structure analysis software ETABS

Results for midrise unsymmetrical C, L and Z type buildings are obtained from structural analysis software CSI ETABS and plotted in the form of curve and their behavior is obtained for different seismic zone.

Storey Displacements for L, C, Z shape building

The results of storey displacement for L, C and Z shaped building under seismic zone 3,4 and 5 are tabulated in Table 3, 4, and 5 respectively. A curve is drawn between the storey displacement and storey number is shown in Fig 4, 5 and 6.

Table no 3 Storey Displacement for Seismic zone 3

Story No	L-Shape	C-Shape	Z-Shape
Story1	1.484	1.373	1.354
Story2	3.704	3.4	3.363
Story3	6	5.487	5.438
Story4	8.264	7.538	7.485
Story5	10.44	9.503	9.455
Story6	12.467	11.329	11.292
Story7	14.275	12.952	12.934
Story8	15.782	14.297	14.306
Story9	16.899	15.284	15.328
Story10	17.561	15.85	15.934

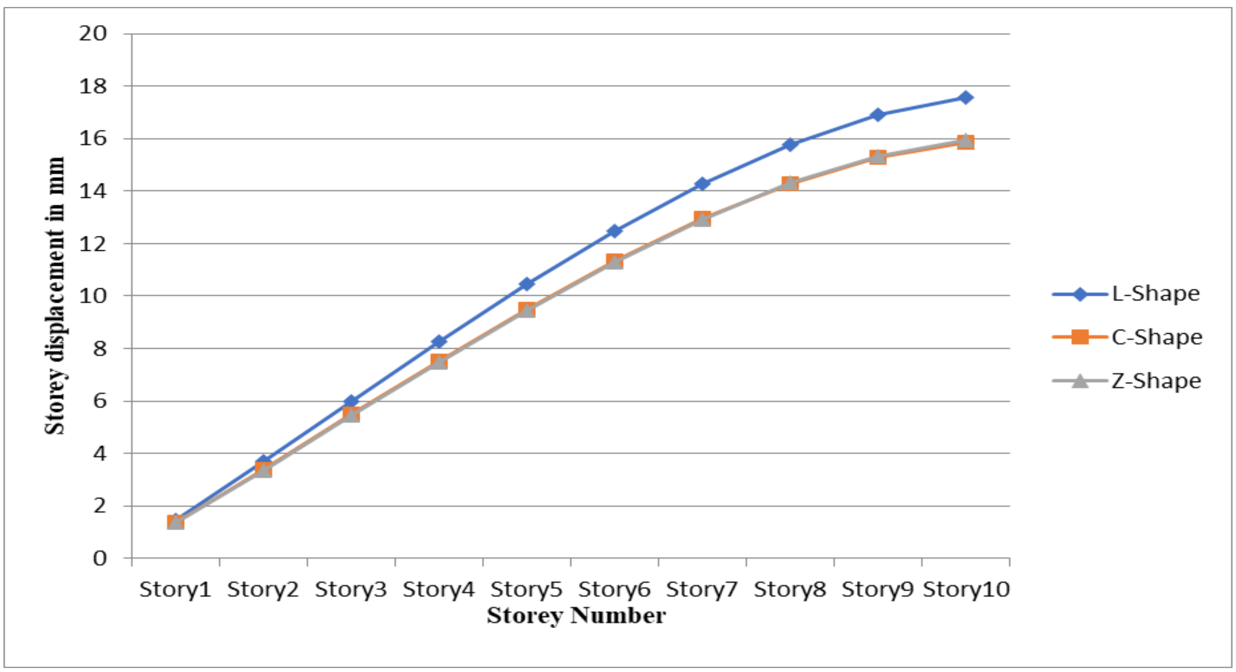

Fig 4 Storey Displacement for Seismic zone 3

Table no 4 Storey Displacement for Seismic zone 4

	L-Shape	C-Shape	Z-Shape
Story1	2.225	2.06	2.03
Story2	5.554	5.104	5.039
Story3	8.999	8.239	8.147
Story4	12.396	11.321	11.211

Story5	15.661	14.276	14.155
Story6	18.703	17.023	16.901
Story7	21.418	19.467	19.352
Story8	23.682	21.496	21.399
Story9	25.361	22.986	22.917
Story10	26.359	23.846	23.814

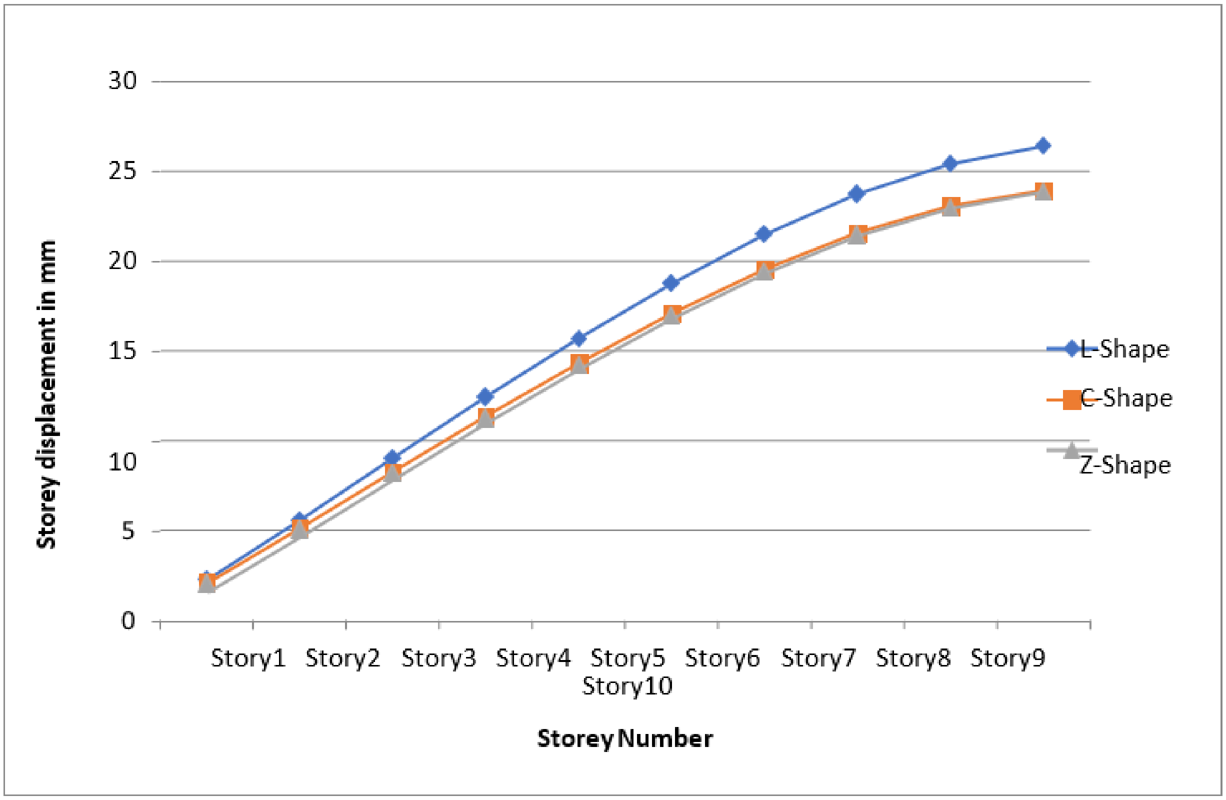

Fig 5 Storey Displacement for Seismic zone 4

Table no 5 Storey Displacement for Seismic zone 5

	L-Shape	C-Shape	Z-Shape
Story1	3.339	2.859	3.044
Story2	8.334	7.055	7.554
Story3	13.505	11.402	12.211
Story4	18.606	15.684	16.799
Story5	23.51	19.794	21.207
Story6	28.083	23.622	25.315
Story7	32.166	27.033	28.98
Story8	35.575	29.873	32.037
Story9	38.107	31.968	34.302
Story10	39.614	33.228	35.634

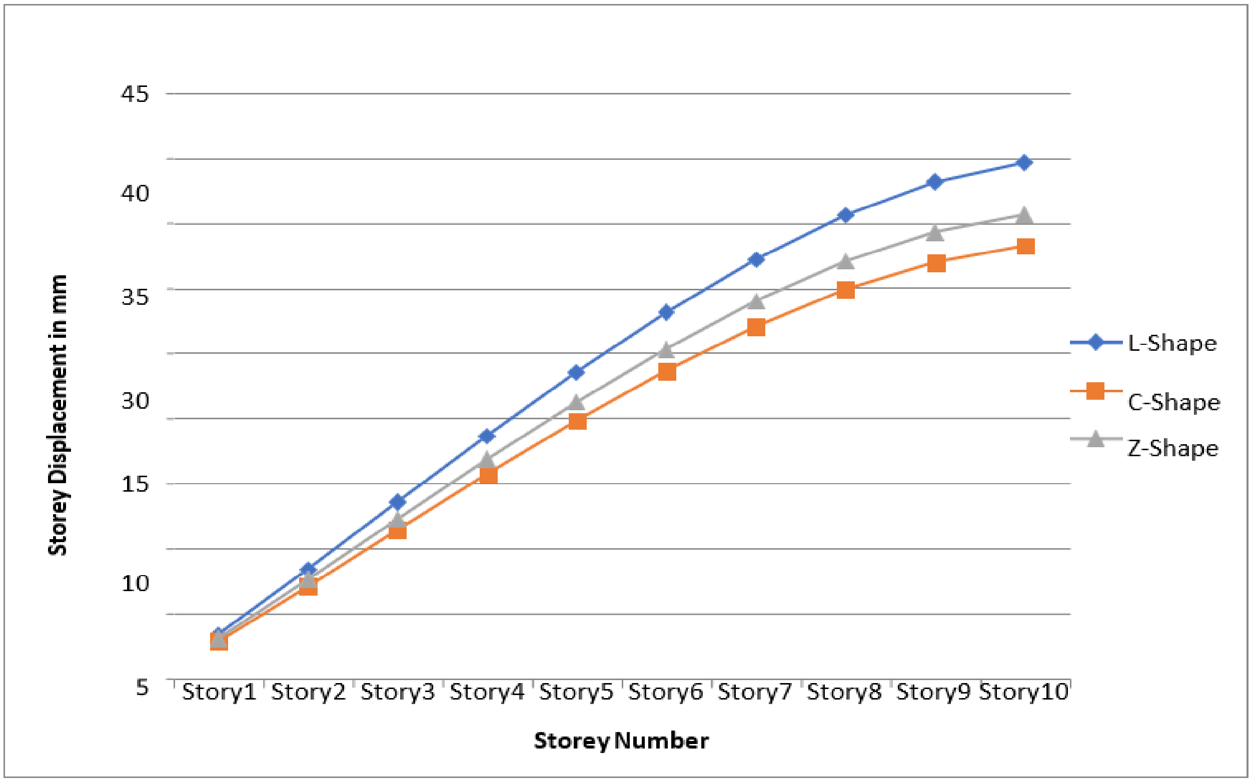

Fig 6 Storey Displacement for Seismic zone 5

From above tables and curves it is observed that storey displacements are greater for L- shape (17.561mm, 26.359mm) building, and approximately similar for C shape (15.85mm,23.846mm) & Z shape (15.934mm, 23.814mm) type building for seismic zone 3 and respectively. However, in zone 5 these structure shows different value of storey displacement, that is in descending order as L shape (39.614mm), Z shape (35.634mm), C- shape (33.228mm) building.

All values of storey displacement are within permissible limit of i.e., 60mm. (permissible limit for storey displacement is H/500, where 'H' is total height of building as per IS 1893)

Storey Drift for L, C, Z shape building

The results of storey drift for L, C and Z shaped building under seismic zone 3,4 and 5 is tabulated in Table 5.4. A curve is drawnbetween the storey drift and storey number is shown in Fig 5.4

Table no 6 Storey Drift for Seismic zone 3

	L-Shape	C-Shape	Z-Shape
Story1	0.000495	0.000458	0.000451
Story2	0.00074	0.000676	0.000669
Story3	0.000766	0.000696	0.000692
Story4	0.000755	0.000684	0.000682
Story5	0.000725	0.000655	0.000656
Story6	0.000676	0.000609	0.000612
Story7	0.000603	0.000541	0.000547
Story8	0.000503	0.000449	0.000457
Story9	0.000372	0.000329	0.00034
Story10	0.000221	0.000189	0.000202

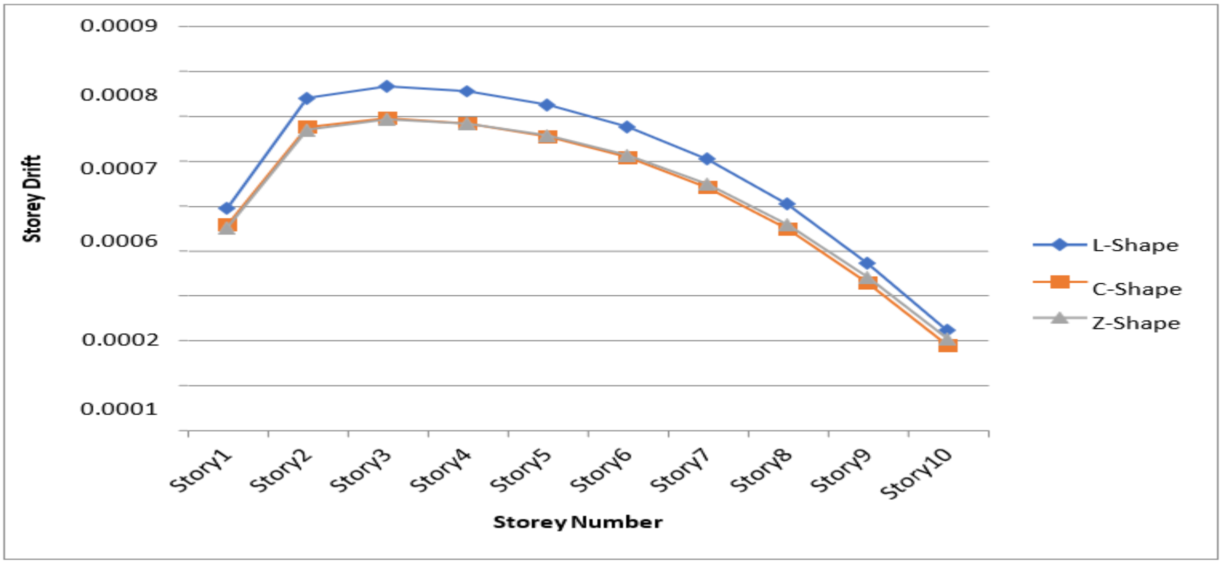

Fig 7 Storey Drift for Seismic zone 3

Table no 7 Storey Drift for Seismic zone 4

	L-Shape	C-Shape	Z-Shape
Story1	0.000742	0.000687	0.000677
Story2	0.00111	0.001015	0.001003
Story3	0.001148	0.001045	0.001036
Story4	0.001132	0.001027	0.001021
Story5	0.001088	0.000985	0.000982
Story6	0.001014	0.000916	0.000915
Story7	0.000905	0.000815	0.000817
Story8	0.000755	0.000676	0.000682
Story9	0.00056	0.000497	0.000506
Story10	0.000333	0.000287	0.000299

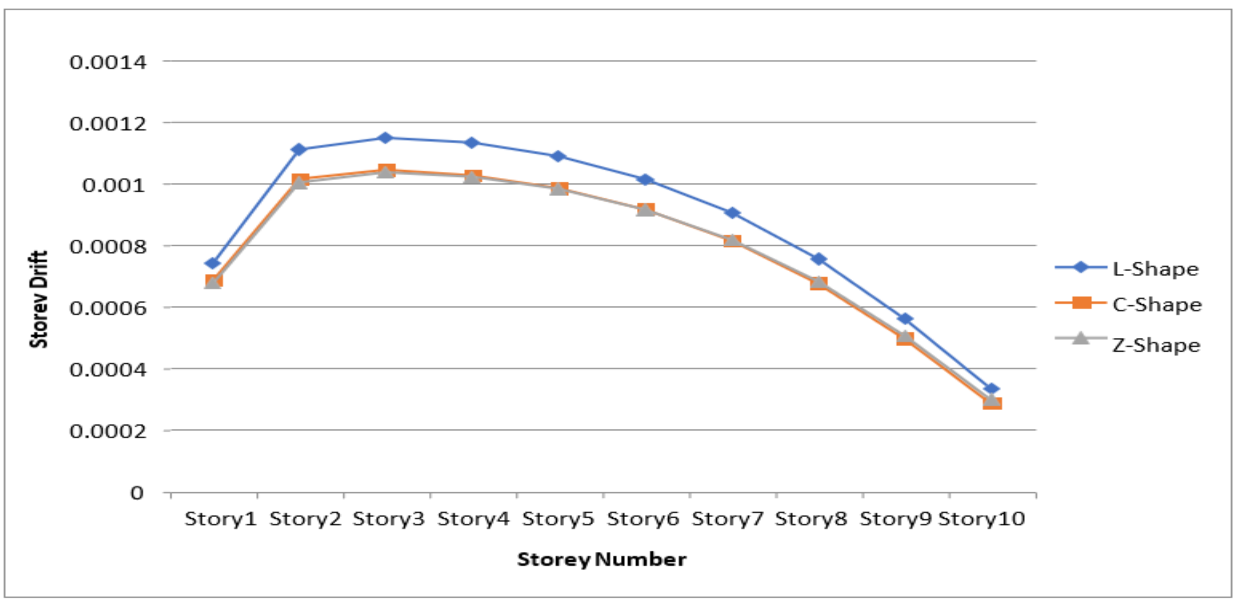

Fig 8 Storey Drift for seismic zone 4

Table no 8 Storey Drift for seismic zone 5

	L-Shape	C-Shape	Z-Shape
Story1	0.001113	0.000953	0.001015
Story2	0.001665	0.001408	0.001503
Story3	0.001724	0.001449	0.001552
Story4	0.0017	0.001427	0.001529
Story5	0.001635	0.00137	0.001469
Story6	0.001524	0.001276	0.001369
Story7	0.001361	0.001137	0.001222
Story8	0.001136	0.000947	0.001019
Story9	0.000844	0.000699	0.000755
Story10	0.000502	0.000425	0.000444

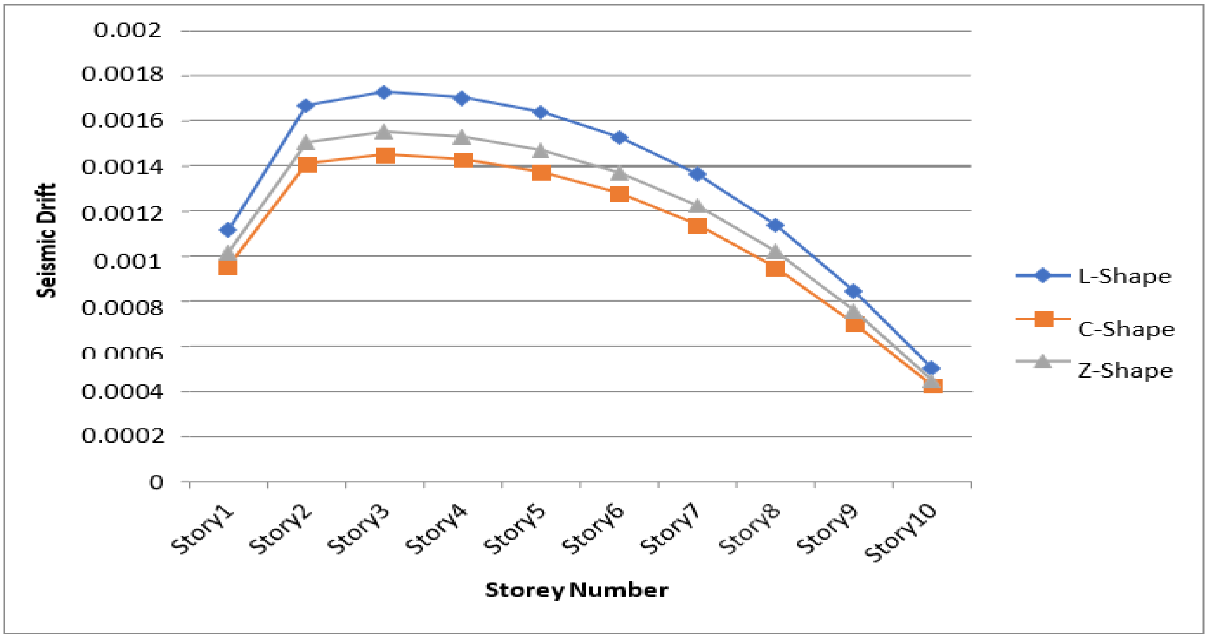

Fig 9 Storey Drift for seismic zone 5

From above curve it is observed that storey drifts are greater for L-shape (0.000755, 0.001148) building, and approximately similar for C shape (0.000696, 0.001045) & Z shape (0.000692, 0.001036) building for seismic zone 3 and 4 respectively. However, in zone 5 these structure shows different value of storey drift, that is in descending order as Lshape (0.001724), Z shape (0.001552), C-shape (0.001449) building. These are maximum values of storey drift observed at story number 3.

All values of storey drift are within permissible value storey displacement i.e., 0.012mm. (permissible limit for storey drift can be calculated as 0.004H, where H is storey height asper IS 1893)

Storey Shear for L, C, Z shape building

Storey shear can be defined as the lateral force acting on a storey due to the forces such asseismic and wind force. Buildings having lesser stiffness attract lesser storey shear and viceversa. The storey shear curve shows the height-wise distribution of storey shears and lateral forces. The results of storey shear for L, C and Z shaped building under seismic zone 3 is tabulated in Table 9,10 and 11. A curve is drawn between the storey shear and storey number is shown in Fig 10,11 and 12.

Table no 9 Storey Shear for Seismic zone 3

	L-Shape	C-Shape	Z-Shape
Story1	2365.6397	2506.4661	2506.6154
Story2	2359.2688	2499.7464	2499.8868
Story3	2333.9057	2472.8677	2473.0066
Story4	2276.8386	2412.3906	2412.5261
Story5	2175.386	2304.8757	2305.0052
Story6	2016.8664	2136.8837	2137.0037
Story7	1788.5981	1894.9752	1895.0816
Story8	1477.8996	1565.7108	1565.7988
Story9	1072.0893	1135.6513	1135.7151
Story10	558.4857	591.3572	591.3904

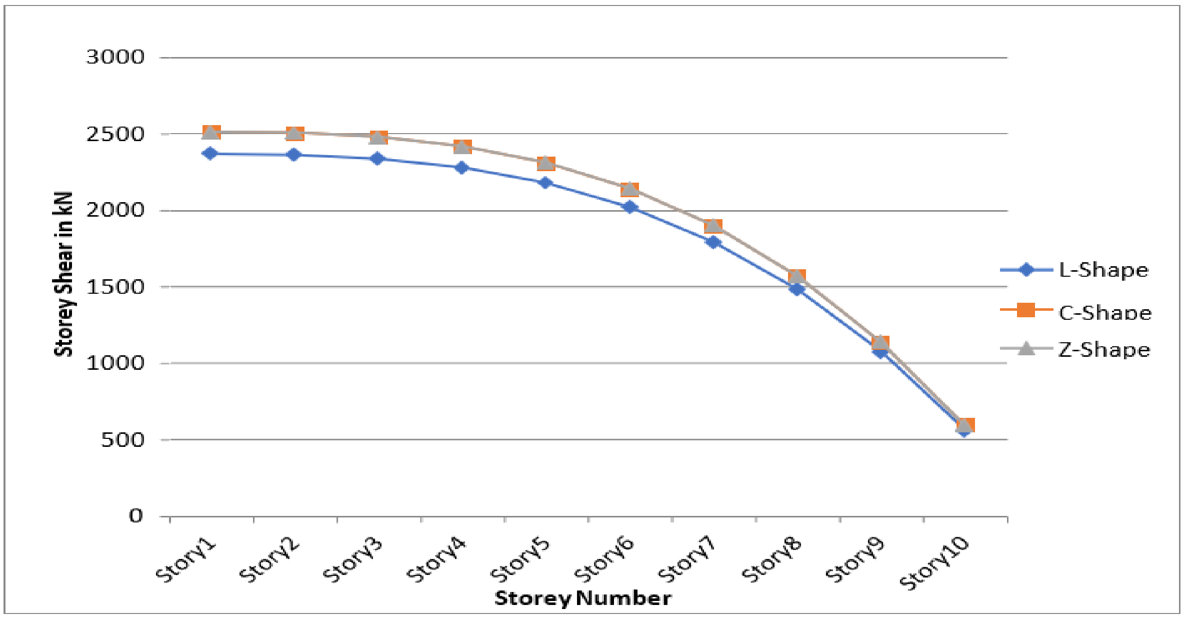

Fig 10 Storey Shear for seismic zone 3

Table no 10 Storey Shear for Seismic Zone 4

	L-Shape	C-Shape	Z-Shape
Story1	3548.506	3759.6992	3759.9231
Story2	3538.9895	3749.6197	3749.8303
Story3	3500.9232	3709.3016	3709.5099
Story4	3415.2742	3618.5859	3618.7891
Story5	3263.0093	3457.3136	3457.5077
Story6	3025.0954	3205.3255	3205.5056
Story7	2682.4994	2842.4628	2842.6224
Story8	2216.1881	2348.5663	2348.6982
Story9	1607.1285	1703.4769	1703.5726
Story10	838.2023	887.0357	887.0855

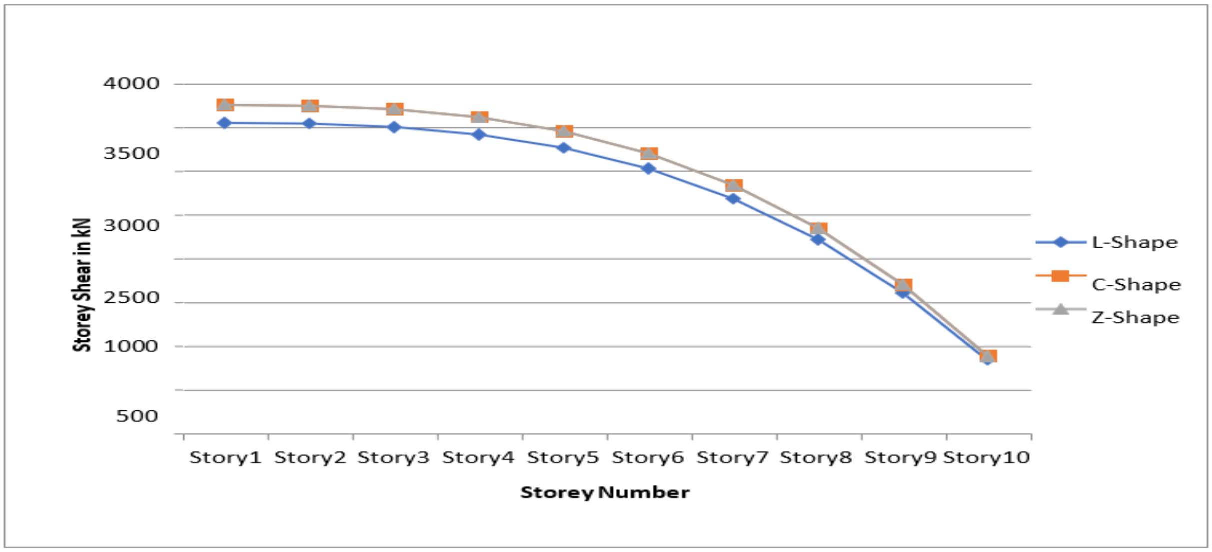

Fig 11 Storey Shear for Seismic zone 4

Table no 11 Storey Shear for seismic zone 5

	L-Shape	C-Shape	Z-Shape
Story1	5316.6046	5639.3749	5639.8655
Story2	5302.3587	5624.2561	5624.7454
Story3	5245.3751	5563.7809	5564.2649
Story4	5117.1621	5427.7115	5428.1837
Story5	4889.2277	5185.8105	5186.2616
Story6	4533.0803	4807.8401	4808.2583
Story7	4020.228	4263.5627	4263.9336
Story8	3322.1791	3522.7408	3523.0472
Story9	2410.4417	2555.1366	2555.3589
Story10	1256.524	1330.5126	1330.6283

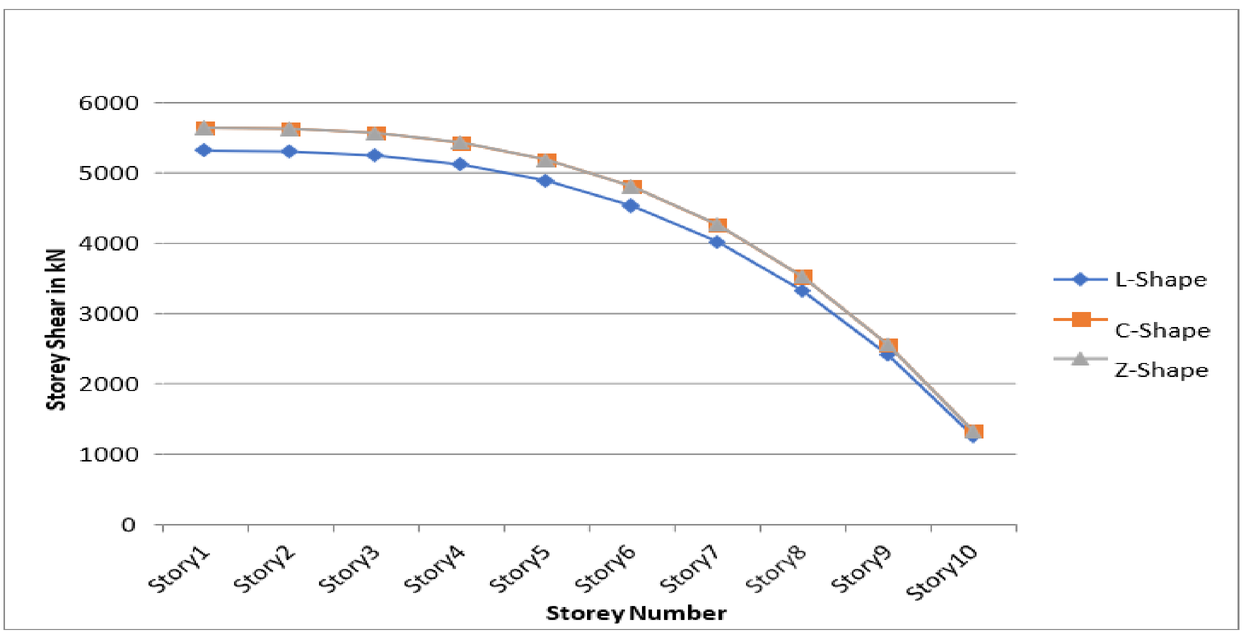

Fig 12 Storey Shear for seismic zone 5

From above tables and curves it is observed that storey shear values are smaller for L shaped (2365.6397kN, 3548.506kN,5316.6046kN) building, and approximately similar for C shaped (2506.4661kN, 3759.6992kN, 5639.3749kN) & Z shaped (2506.6154kN,3759.9231kN,5639.8655kN) type building for seismic zone 3,4, &5 respectively.

Base shear for L, C, Z shape building

Base shear is an estimate of the maximum expected lateral force on the base of the structure due to seismic activity Base shear for L, C, Z shape building for different seismic zone.

Table 12 Base Shear for L, C, Z Building under Different Seismic Zone

Seismic Zone	L Shaped	C Shaped	Z Shaped
Zone 3	2365	2506	2506
Zone 4	3548	3759	3759
Zone 5	5316	5639	5639

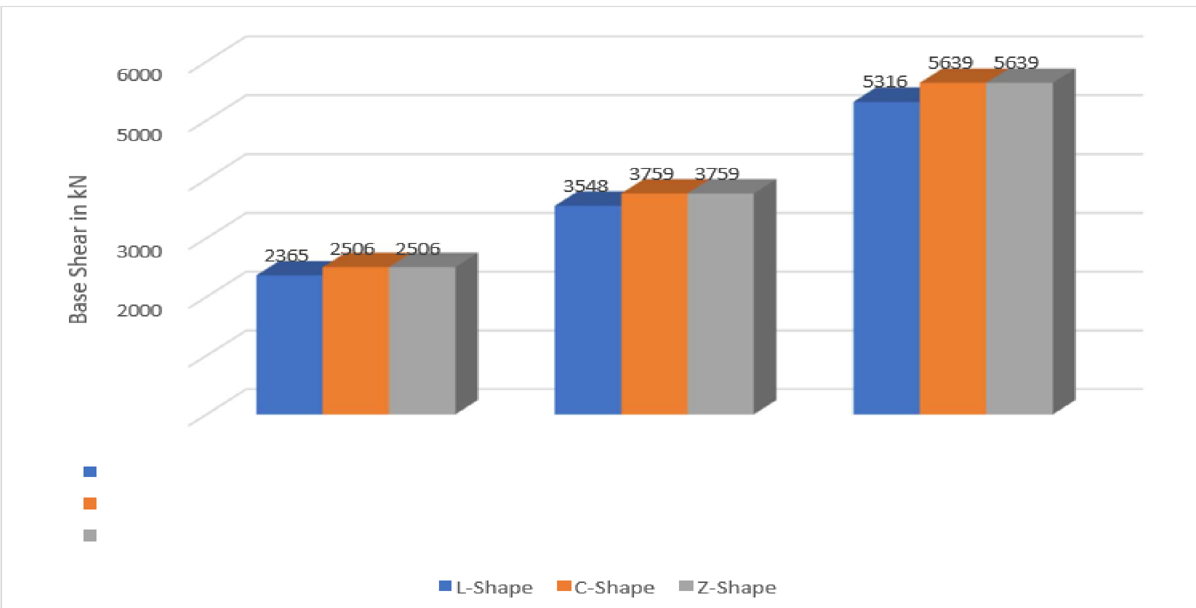

Fig 13 Bar graph for base shear with respect to storey number in different seismic zone.

0	Zone 3	Zone 4	Zone 5
L-Shape	2365	3548	5316
C-Shape	2506	3759	5639
Z-Shape	2506	3759	5639

From above curve it is observed that base shear value is smaller for L-shape building (2365kN, 3548kN,5316kN), and approximately similar for C shaped (2506kN, 3759kN, 5639kN) & Z shaped (2506kN, 3759kN, 5639kN) type building for seismic zone 3, 4 and 5.

Axial Force acting on Foundation.

The axial force in Z direction and moments in X and Y direction acting on interface of ground is obtained from CSI ETABS software. The values of axial forces are very important parameter for the design of the foundation and decision of foundation type depends on it. If the column spacing and size of individual footing overlaps, then combinedfooting are provided. Even if the choice of combined footing is ruled out one can go for strip footing (a common footing for all column on a common axis) is used. Even if strip footing is not possible then the possibility of raft foundation is examined.

Fig no 14 Numbering of column for L-shape building

Table 13 The value of column loads on ground for L-shape building under seismic zone 3,4 and 5

Node number	Seismic Zone 3 (In Kn)	Seismic Zone 4 (In Kn)	Seismic Zone 5 (In Kn)
1	2388.3	2475.4	2678.6
2	3306.6	3308.9	3309.9
3	3390.1	3383.9	3394.1
4	3285.1	3251.5	3309.6
5	2355.3	2449.1	2679.4
6	3314.4	3314.8	3313.9
7	4425.5	4423.4	4423.6
8	4517.3	4512.4	4520.6
9	4403.2	4374.6	4424.6
10	3287.8	3253.9	3312.5
11	3402.1	3403.1	3402.2
12	4525.1	4525.1	4525.6
13	4625.3	4624.2	4626.1
14	4539.2	4534.3	4542.6
15	3479.9	3473.7	3483.9
16	3406.6	3466.7	3406.1
17	4529.1	4529.4	4529.3
18	4632.3	4632.2	4632.3
19	4601.2	4601.2	4601.5
20	4244.9	4244.2	4244.7
21	3483.7	3483.7	3483.9
22	3312.2	3314.4	3312.4
23	2382.8	2474.2	2679.4
24	3406.4	3406.5	3406.1
25	4529.1	4529.1	4529.1
26	4633.3	4633.3	4633.3
27	4632.3	4632.3	4632.2
28	4601.1	4601.5	4601.1
29	4538.8	4542.6	4542.6
30	4413.8	4424.5	4424.6
31	3305.4	3309.1	3309.6
32	3402.3	3402.5	3402.1
33	4524.5	4524.5	4524.5

34	4628.8	4628.7	4628.8
35	4633.3	4633.3	4633.3
36	4631.4	4632.3	4632.3
37	4606.3	4626.1	4626.1
38	4378.4	4520.6	4520.6
39	3373.5	3393.7	3394.1
40	3314.3	3314.3	3314.1
41	4423.2	4423.2	4423.1
42	4524.5	4525.5	4524.4
43	4529.1	4529.1	4529.1
44	4528.4	4529.3	4529.3
45	4505.4	4525.1	4523.1
46	4281.3	4423.6	4423.6
47	3289.4	3309.8	3309.9
48	2393.1	2479.9	2683.1
49	3314.4	3314.8	3314.1
50	3402.4	3402.7	3402.1
51	3406.3	3406.5	3406.1
52	3405.9	3406.4	3406.1
53	3398.5	3402.4	3402.2
54	3303.1	3314.0	3313.9
55	2384.1	2475.2	2678.6

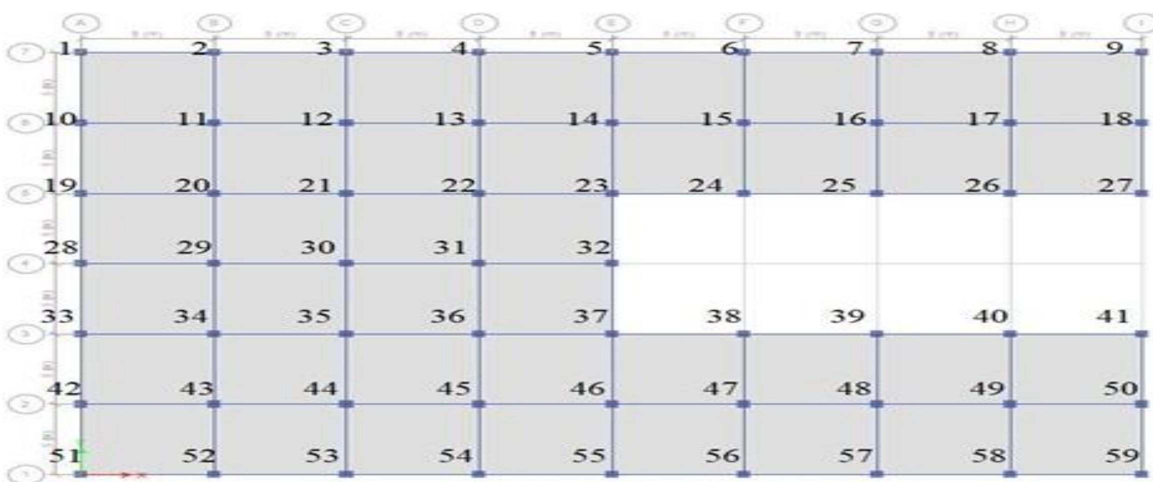

Fig no 15 Numbering of column for C-shape building

Table 14 The values of column loads on ground for C-shape building under different seismic zone

Node number	Seismic Zone 3	Seismic Zone 4	Seismic Zone 5
1	2392.3	2481.3	2684.5
2	3311.8	3311.8	3311.2
3	3399.8	3399.8	3399.3
4	3403.6	3403.6	3403.1
5	3402.4	3402.4	3402.0
6	3401.7	3401.7	3401.3
7	3397.0	3397.0	3396.6
8	3308.6	3308.6	3308.1
9	2381.3	2479.6	2686.9
10	3315.9	3315.9	3315.0
11	4423.2	4423.2	4423.7

12	4524.2	4524.1	4524.8
13	4522.8	4522.8	4523.5
14	4491.4	4491.4	4492.1
15	4437.9	4437.8	4438.5
16	4417.3	4417.3	4418.0
17	4317.4	4317.4	4317.9
18	3215.8	3215.8	3214.9
19	3404.2	3404.2	3403.4
20	4524.9	4524.9	4525.6
21	4627.8	4627.8	4628.5
22	4598.1	4598.1	4598.8
23	4243.0	4243.0	4243.7
24	3487.3	3487.3	3488.1
25	3400.3	3400.2	3401.1
26	3308.4	3308.4	3309.0
27	2381.3	2491.5	2704.9
28	3408.6	3408.6	3407.8
29	4530.2	4530.2	4530.9
30	4632.4	4632.4	4633.1
31	4565.3	4565.3	4566.0
32	3573.6	3573.6	3574.1
33	3404.2	3404.2	3403.4
34	3524.9	4524.9	4525.6
35	4627.8	4627.8	4628.5
36	4598.1	4598.1	4598.8
37	4243.0	4243.0	4243.7
38	3487.3	3487.3	3488.1
39	3400.2	3400.2	3401.1
40	3308.4	3308.4	3309.0
41	2381.3	2491.5	2704.9
42	3315.9	3315.9	3315.0
43	4423.2	4423.2	4423.7
44	4524.1	4524.1	4524.8
45	4522.8	4522.8	4523.5
46	4491.4	4491.4	4492.1
47	4437.8	4437.8	4438.5
48	4417.3	4417.3	4418.0
49	4317.4	4317.4	4317.9
50	3215.8	3215.8	3214.9
51	2392.3	2481.3	2684.5
52	3311.8	3311.8	3311.2
53	3399.8	3399.8	3399.3
54	3403.6	3403.6	3403.1
55	3402.4	3402.4	3402.0
56	3401.7	3401.7	3401.3
57	3397.0	3397.0	3396.6
58	3308.6	3308.6	3308.1
59	2381.3	2479.6	2686.9

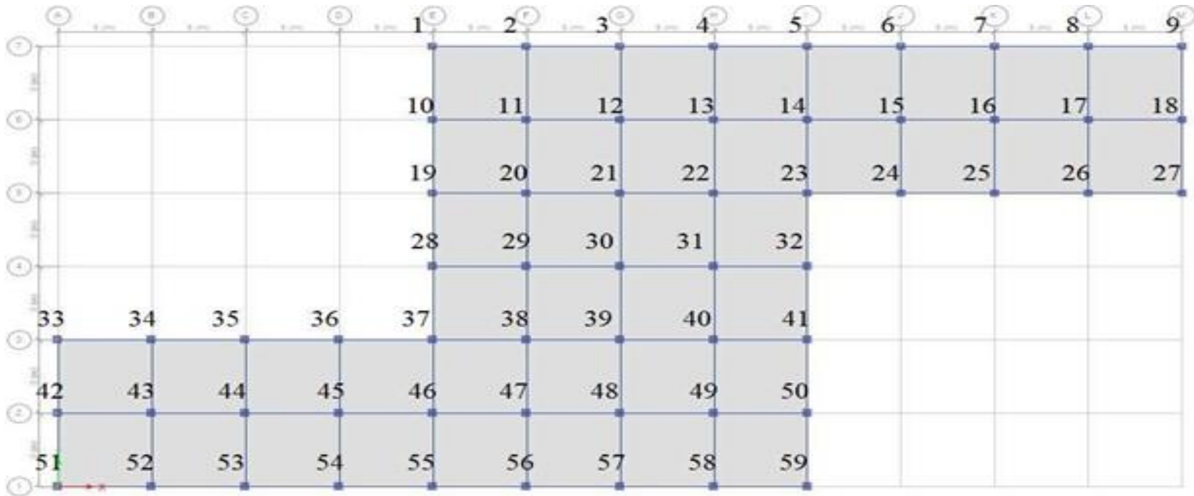

Fig no 16 Numbering of column for Z-shape building

Table 15 The values of column loads on ground for C-shape building under different seismic zone

Node number	Seismic Zone 3	Seismic Zone 4	Seismic Zone 5
1	2392.3	2481.3	2684.5
2	3311.8	3311.8	3311.2
3	3399.8	3399.8	3399.3
4	3403.6	3403.6	3403.1
5	3402.4	3402.4	3402.0
6	3401.7	3401.7	3401.3
7	3397.0	3397.0	3396.6
8	3308.6	3308.6	3308.1
9	2381.3	2479.6	2686.9
10	3315.9	3315.9	3315.0
11	4423.2	4423.2	4423.7
12	4524.2	4524.1	4524.8
13	4522.8	4522.8	4523.5
14	4491.4	4491.4	4492.1
15	4437.9	4437.8	4438.5
16	4417.3	4417.3	4418.0
17	4317.4	4317.4	4317.9
18	3215.8	3215.8	3214.9
19	3404.2	3404.2	3403.4
20	4524.9	4524.9	4525.6
21	4627.8	4627.8	4628.5
22	4598.1	4598.1	4598.8
23	4243.0	4243.0	4243.7
24	3487.3	3487.3	3488.1
25	3400.3	3400.2	3401.1
26	3308.4	3308.4	3309.0
27	2381.3	2491.5	2704.9
28	3408.6	3408.6	3407.8
29	4530.2	4530.2	4530.9
30	4632.4	4632.4	4633.1
31	4565.3	4565.3	4566.0
32	3573.6	3573.6	3574.1
33	3404.2	3404.2	3403.4
34	3524.9	4524.9	4525.6
35	4627.8	4627.8	4628.5

36	4598.1	4598.1	4598.8
37	4243.0	4243.0	4243.7
38	3487.3	3487.3	3488.1
39	3400.2	3400.2	3401.1
40	3308.4	3308.4	3309.0
41	2381.3	2491.5	2704.9
42	3315.9	3315.9	3315.0
43	4423.2	4423.2	4423.7
44	4524.1	4524.1	4524.8
45	4522.8	4522.8	4523.5
46	4491.4	4491.4	4492.1
47	4437.8	4437.8	4438.5
48	4417.3	4417.3	4418.0
49	4317.4	4317.4	4317.9
50	3215.8	3215.8	3214.9
51	2392.3	2481.3	2684.5
52	3311.8	3311.8	3311.2
53	3399.8	3399.8	3399.3
54	3403.6	3403.6	3403.1
55	3402.4	3402.4	3402.0
56	3401.7	3401.7	3401.3
57	3397.0	3397.0	3396.6
58	3308.6	3308.6	3308.1
59	2381.3	2479.6	2686.9

After analyzing the building of chosen shape and seismic zone, the reaction forces on foundation nodes are noted from software (ETABS). Table no 5.11 shows value of the axialforces in the direction of gravity i.e., the vertical forces at different nodes for C-Shaped building under different seismic zone. Table 5.12 and Table 5.13 shows the value of axialforces for L and Z shape building. It is found that the values in other two direction are negligible.

From above all tables, we can conclude that the maximum value for column load is same for all C, L and Z type structure (i.e., 4632kN for at central column).

CONCLUSION

Based upon the detailed analysis conducted on three different type of unsymmetrical structure buildings under three different zone using different readymade software following conclusions can be drawn.

- For column load, we can conclude that the maximum value for column load is samefor all C, L and Z type structure. (i.e., 4632kN at central column)
- For storey displacements, it can be concluded that it is greater for L-shape (17.561mm, 26.359mm) building, and approximately similar for C shape (15.85mm, 23.846mm) & Z shape (15.934mm, 23.814mm) type building for seismic zone 3 and 4 respectively. However, in zone 5 these structure shows different value of storey displacement, that is in descending order as L shape (39.614mm), Z shape (35.634mm), C-shape (33.228mm) building.
- For storey drift, it can be concluded that storey drifts are greater for L-shape (0.000755, 0.001148) building, and approximately similar for C shape (0.000696, 0.001045) & Z shape (0.000692, 0.001036) building for seismic zone 3 and 4 respectively. However, in zone 5 these structure shows different value of storey drift, that is in descending order as L shape (0.001724), Z shape (0.001552), C- shape (0.001449) building. These are maximum values of storey drift observed at story number 3.
- For storey shear, it can be concluded that storey shear values are smaller for L shaped (2365.6397kN, 3548.506kN, 5316.6046kN) building, and approximately similar for C shaped (2506.4661kN, 3759.6992kN, 5639.3749kN) & Z shaped(2506.6154kN,3759.9231kN,5639.8655kN) type building for seismic zone 3,4,&5 respectively.
- For base shear, it can be concluded that, its value is smaller for L-shape building (2365kN,

3548kN,5316kN), and approximately similar for C shaped (2506kN, 3759kN, 5639kN) & Z shaped (2506kN, 3759kN, 5639kN) type building for different seismic zone.

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